Instrument Issue

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SCIENCE

26 October 1956

Volume 124, Number 3226

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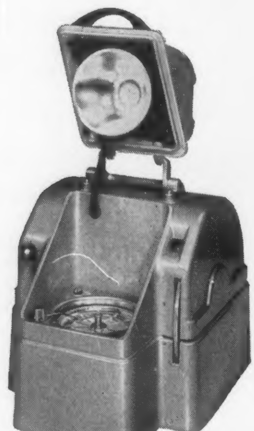

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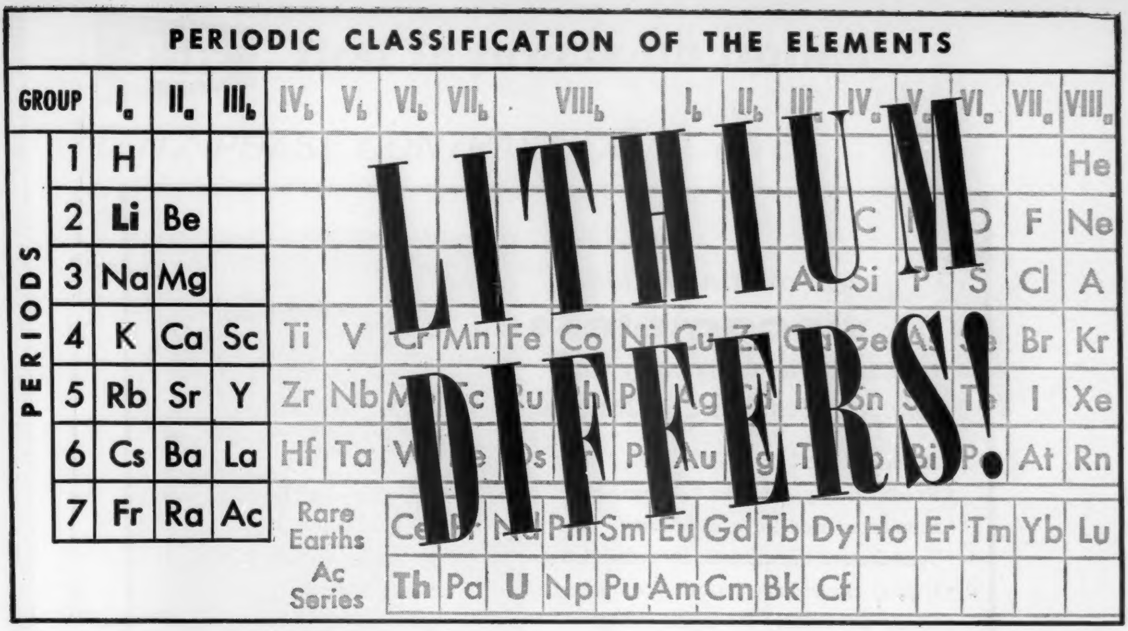

Lithium, by reason of its atomic configuration and general characteristics, is rightfully included as the first member of Group I in the Periodic Table. A detailed study of the properties and reactions of both the elements and their compounds, however, shows that Lithium often resembles the metals of Groups II and III more closely than Group I. Following are some characteristic differences:

Lithium differs in organic chemistry . . .

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Lithium differs in metallurgy...

inasmuch as the affinity of Lithium for oxygen, for example, is being utilized to reduce porosity in copper and copper alloy castings. Recent research has revealed that Lithium will produce brazing alloys with self-fluxing properties and increase the wetting ability of these alloys.

Lithium differs in inorganic chemistry . . .

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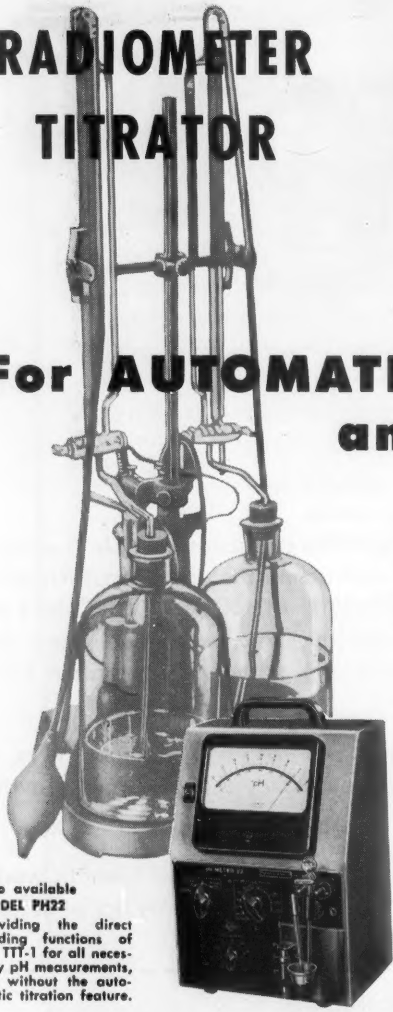

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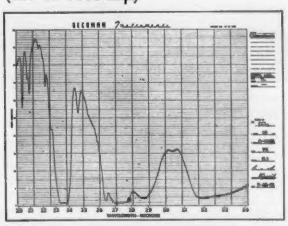

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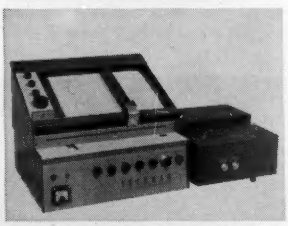

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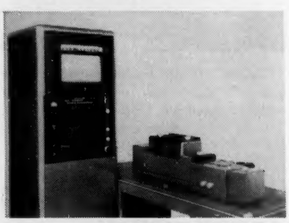

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SCIENCE is indexed in the *Reader's Guide to Periodical Literature* and in the *Industrial Arts Index*.

Editorial and personnel-placement correspondence should be addressed to SCIENCE, 1515 Massachusetts Ave., NW, Washington 5, D.C. Manuscripts should be typed with double spacing and submitted in duplicate. The AAAS assumes no responsibility for the safety of manuscripts or for the opinions expressed by contributors. For detailed suggestions on the preparation of manuscripts, book reviews, and illustrations, see *Science* 123, 714 (27 Apr. 1956).

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Instruments and Man

By devoting this issue of *Science* largely to instruments, we recognize the important part that instruments play in modern science, technology, and business organization.

Everyone is familiar, at least by hearsay, with some of the achievements made possible by modern instruments, achievements in the development of sensing devices capable of operating under extreme conditions and sensitive to physical changes far beyond the range of human sense organs, computing machines of extreme rapidity, and devices for automatic control of machining and assembling operations.

There can be no serious question about the indispensability of the new instruments for scientific advance: many current discoveries would have been quite impossible without use of the specially designed instruments made possible by modern technology, instruments that could not have been devised at an earlier stage in history. Improved instruments will surely be no less important for research progress in the future.

This is all to the good. But a good many people are less certain about the benefits of the application of instrumental processes to factories and offices. The automatic factory and the automatic office are no longer dreams of the future; they are already present and will be more abundant in the future.

No one can forecast how rapidly conversion to automatic factories and offices will occur, but a glimpse into the future can be obtained by considering the program of the Third International Automation Exposition to be held in New York City next month. The titles of two conferences sponsored by the exposition are signposts to the future: "Human engineering—automation and man" and "The challenge of automatic data processing to senior officers." The exposition has arranged 54 "clinic classes" to acquaint industrialists with the machinery of automation. The classes will be grouped under the following headings: office automation and data handling; process automation; analog computers; digital computers; electronic, hydraulic, pneumatic, and electromechanical techniques; automatic production, assembly, cleaning, and fabrication; servomechanisms; and optical techniques.

Increased automation will undoubtedly intensify the changes that have been under way since the beginning of the industrial revolution in the conditions of employment and the use of leisure. Whether or not we can, as some think, gradually adjust to these changes without major unheaval remains to be seen. Our past history gives us grounds for hope.—G. DuS.

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Data Processing for Scientists

Karl F. Heumann

It is the thesis of this article that scientists can expect, and indeed can demand, more assistance from machines in the matter of scientific data handling (*1*). This will be available through the use of techniques which have had a recent, rapid development in business and accounting applications.

Two of these techniques are considered here in their relation to science: integrated data processing (IDP) and electronic data processing (EDP). My plan is first to provide a short background in the concepts of IDP and EDP through a consideration of the reasons for their development in business. This is followed by several case-histories of successful applications and by some information on the machines involved. Finally, I want to connect this to the related problem of scientific information storage and use by discussing current work in classification and indexing, closing with some recent work on computers that points toward increased use in the future.

The scope of the discussion is limited for a number of reasons. There has been a flood of books and articles on this subject which have, by the way, not been adequately handled by bibliographic means. The only extensive bibliography (*2*), for instance, has neither a subject nor an author arrangement. Preparation of an authoritative bibliography on data processing containing adequate indexes would be a timely venture.

Another limitation of the subject matter must be understood. No mention is made here of operations research, linear or other programming, game theory, information theory, and other new disciplines that touch the matter at some point. The use of these disciplines is mentioned in several of the books noted in "References and Notes."

Dr. Heumann is on the staff of the Chemical Abstracts Service, Ohio State University, Columbus.

Definition and Origin of IDP

Early in 1954, the American Management Association held a conference on "Integrating the office for electronics," which described the pioneer work of the U. S. Steel Corporation in office mechanization. Apparently, it was here that the phrase "integrated data processing" was first publicly used. A published report (*3*) of the conference gives a statement about the elements of IDP. They are two: (i) Creation of a document is accompanied by recording of the data in mechanical form. (ii) Subsequent processing of the data is done mechanically in an integrated system.

Closely connected with this original statement is the concept of a "common language" (*3*, p. 9). This refers to a means by which IDP can be carried out, in this case a group of machines that can interchange data through the use of the same impulse-code for each symbol involved. The U.S. Steel program decided on the five-channel punched paper tape (Fig. 1), already used with telecommunications equipment, as the carrier for this common language, and it has been widely adopted. More is said on this later.

Unfortunately for a scientific audience, *data* here is used to mean almost any business information whatever, such as that involved in accounting, sales, or payroll handling. We shall come back to a more familiar use of it later on. *Processing* refers to any subsequent use of the information or "data," and in this context it is used to mean processing by way of some machine.

Electronic data processing (*4*, *5*), by contrast, does not have a sharp beginning but developed through the use of large-scale computers, in experimental trials. It is evident that the two concepts merge where any electronic components are used in an integrated system. The advantages, of course, are the speed, flexibility, and capacity of such devices. It, nevertheless, remains true that it is possible to use an electronic data processor without having an integrated system.

It seems reasonable to refer to work in this area as *data processing*, and to reserve *automation* for the handling of materials by mechanical control, although the terms have been used interchangeably (*6*).

Let us consider why an industry would scrap long-used office procedures for a method that is often initially of little economic advantage and raises important management and personnel problems. I believe the answer is in the future value that a company can hope to gain by having its paperwork under tight control, with a concurrent reduction in its clerical force. The implications that this rather trite statement has for science and its problems should concern us all. Do we, at present, have good bibliographic control over the documents that we produce? Consider government research reports or atomic energy literature. Are we committed to a situation in which an ever-larger number of our dwindling supply of scientists act as "clerical workers," through failure to apply scientific methods to science's own record? The example of another area of human activity—namely, business—can show us a pertinent model here for recasting our own procedures.

Business Applications

What are some of the applications that have proved successful?

Suppose we look at the pioneer effort, that of U.S. Steel (*3*). This company found that its old procedures for processing of data about its procurement, manufacture, and sale of products were falling behind the requirements of management for prompt information. The redesign of parts of the system would not remedy this situation. Partial mechaniza-

tion led only to an increase in repetitive keyboard entries of the same data.

Fortunately the suppliers of office equipment were receptive to a new approach, and in the past few years they have brought out a variety of machines, such as adding machines, electric typewriters, printers, and bookkeeping machines, which either accept or create the five-channel common-language tape. As an example, this has enabled the U.S. Steel Corporation to prepare, for each Monday morning, an accurate inventory, as of the previous Friday afternoon, of up to 200 models in each of 130 different locations, with a variety of data on each individual model. This, of course, is a single link in a highly integrated chain of procedures.

Another instructive example exists in the program now used by the Aluminum Company of America for handling orders (7). An integrated system takes order tapes, which have been prepared in more than 60 sales offices, and transmits them through a teletypewriter switching center at the rate of 1000 per day to 24 different plants. The five-channel punched paper tape again carries the common language. Initial recording on a tape-cutting typewriter starts a series of repetitions which ultimately produces duplicates for proof copies, sales orders, salesman's copy, production planning copies, and even shipping labels, besides numerous file copies.

Such tight control of the information flow was achieved by intensive study and redesign of forms and procedures, once the concept of integration was accepted. Several years of work by many people were required to reach the point where successful operation could begin.

A third system, planned with utilization of an electronic data-processing machine in mind, has been developed by the Chesapeake and Ohio Railroad (*8*, pp. 74–122). It is referred to as "The one-shot process," which symbolizes the goal of a single keyboard entry of information.

In 1954, the C. and O. used more than a billion pieces of paper, chief among them being millions of freight waybills. The information on this form was minutely analyzed, by a special methods research team, with regard to the source and future use of each individual entry. It became apparent that extensive duplication existed in later retyping of the

Fig. 2. The Programatic Flexowriter, an important part of many IDP systems.

same information. In combination with other forms, such as car orders and wheel reports, it was possible to plan an integrated system, using the five-channel tape, a teletypewriter network, and a large-scale, general-purpose computer. The input was decentralized so as to include any place where data originated, and the communications network carried it to the central computer. The output goals were as follows: (i) current digested results for management decisions, (ii) exceptions for investigation, and (iii) detailed listings for reference.

A company official, E. L. Morrison, has said (*8*, p. 96): "The ultimate objective of the communications network is the provision, eventually, of a major input for the computer. The design and development work that has gone into the network, the format in which the information is placed, the distribution of that information and the necessary machine coding have been developed to be compatible with this computer use. Thus we have achieved a translation of the information from clerical documents to machine language, performing it by key stroke, in all the varied locations over the railroad. In effect, we have decentralized the key-punching function. The teletypewriter network brings the information all together, in form for processing in the computer.

"The computer can produce, much more quickly and economically than existing methods, many of our current operating reports for management. These reports, by and large, were developed as being the most refined tools that could be produced under a completely manual- and, in some cases, a punched-card-application. But they lack the sophistication which appears necessary for modern management in a progressive industry. We look forward to computer ouptuts contributing to a more informed management judgment in a greater variety of areas, and at an earlier date after the fact, than has ever been previously possible."

Many other, and equally successful, accounting and clerical applications of this general approach already exist.

Some Implications for Science

I have given these three examples because I think they have lessons for the use of similar methods in scientific information handling, lessons for groups such as all the science departments of a university, the research department of a business, or a government laboratory. These places now produce scientific information and are paying for its handling in one way or another.

If such a procedure were considered, one could look forward to steps such as these: (i) There will be a long period of preparation, including a job of getting the concept across to some person or group that can say "go ahead," and support will then be provided. (ii) Forms and procedures will probably require extensive revision or replacement. Incidentally, despite its legal value, what could be more archaic than the handwritten recording of experimental results in the standard laboratory notebook? (iii) It will be of maximum value if the system is completely integrated, with some specific end-use in mind. Fortunately, machines for this goal are already well developed. (iv) Not only will the output be rapid, and of improved accuracy, but it will be possible to provide answers to generic questions not hitherto possible.

Take the man who wishes to test 100 chemical compounds for their effects on 12 species of plants. With replications and a variety of dosages, he can expect to deal with several thousand results of even one technique of application. At present he might report only the successful compounds, but even if a journal were to print all the data, they would usually still be considered as a single bibliographic unit, a "paper." Here is where the item-by-item technique of electronic data processing shows its advantage. The

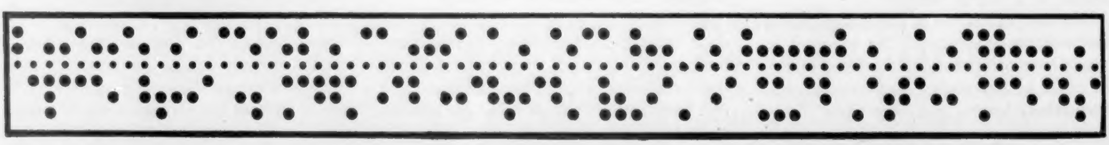

Fig. 1. Five-channel punched paper tape, the "common-language" medium in most integrated data processing. A sprocket channel is near the center.

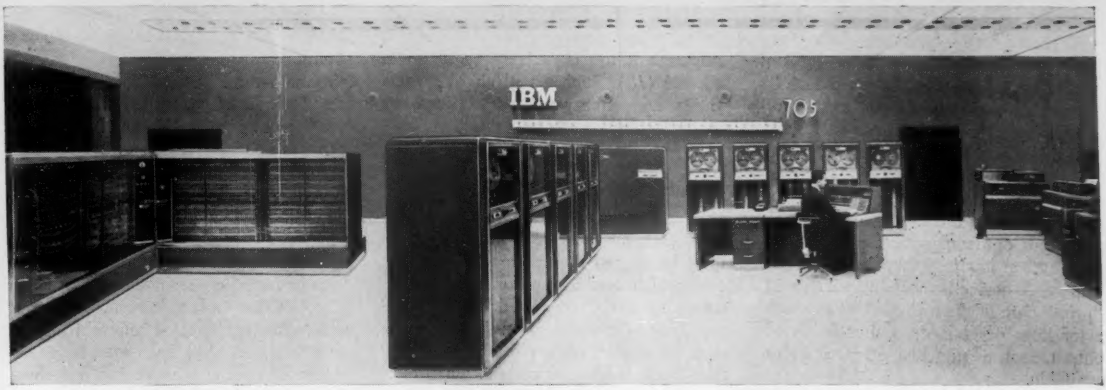

Fig. 3. The IBM type 705 EDPM, a large-scale general-purpose data processor.

complete set of results can be scanned rapidly, arranged, reordered, and analyzed for correlations.

Similar problems in data handling exist in a series of wind-tunnel experiments where the number of variables is large and the speed of analysis could be critical (see later).

I believe any scientist of even moderate acquaintance knows of caches of unused scientific data that would be raw material for such a procedure as the afore-described one. If the Chesapeake and Ohio Railroad considers itself a statistical factory (for the Interstate Commerce Commission), it would not be unrealistic to consider a research laboratory to be an information factory and to plan accordingly.

Some Machines for IDP

It will not be possible to note all the important mechanical devices that are of interest in connection with data processing. Fortunately, several recent books enable one to survey these developments in detail (*4, 9–11*).

In considering integrated data processing, the original keyboard step is generally required to create two copies. One copy is a "graphic" form in which the result of keystrokes is readable—that is, visible—but which may consist of any symbols whatever, for instance, chemical formulas on a sheet of paper. The other copy, in "coded" form, is the same information in some common language, perhaps the five-channel punched-paper tape (Fig. 1), ordinarily used for further machine processing of the information. Each transverse row of holes in such a tape contains in coded form one symbol, such as the letter *R*, or an instruction to the machine.

A widely used input device is the Flexowriter (*12*), an electric typewriter equipped with a tape punch and reader, and the capacity for reproducing tape (Fig. 2). Operation of the machine produces a typewritten sheet of paper (the graphic form) and a by-product tape (the coded form) containing all, or a selected part, of the information. Punching is almost completely automatic. Errors are easily signaled and controlled.

It is also possible to operate a typewriter and punch a standard tabulating card at the same time, or to type and at the same time enter the information onto magnetic tape. Oddly enough, little has been done with cards that carry magnetic spots or strips. Recently, checks have been coded and sorted magnetically (*13*), and there have been several other experiments (*8*, p. 135; *14*).

An ingenious variant is the punching of a standard tabulating card with the usual tabulating punches and also with the five-channel punching along one or several edges (*9*, pp. 54a and 54b). The final card not only carries a code by which it can be sorted but also contains in coded form a means of reproducing text.

Machines also exist which can interconvert between cards and tape. In fact, it is probably safe to say that any standard keyboard device can now also be found in a "common-language" version or can easily be turned into one. With the development of higher-capacity tapes (six-, seven-, and eight-channel forms already exist) almost any device that operates from or into a keyboard could be assimilated into an IDP system.

Larger-Scale EDP Machines

Kozmetsky and Kircher point out (*10*, p. 94) that the significant electronic counterpart to IDP machines is just now beginning to emerge. First came the true computer, the "scientific" computer, which required only moderate input and output but computed at high rates of speed. For applications such as payroll or accounting procedures, the second type, a "general-purpose" computer was developed which could handle large volumes of input and output, in addition to altering each unit record in some way, on usual runs. The third type, and latest to arrive, is the one that seems destined to be most useful for scientific data processing. This "inventory" computer would also be expected to deal with large volumes of input and output data and to perform some logical operations, but in any one run it would refer to only a small part of all the items in the file. These characteristics fit in well with the usual procedures for storage and retrieval of scientific information.

It will suffice here if we consider a large-scale computer and a medium-size computer for electronic data processing, with the understanding that these are representative of groups of similar devices (*4, 9–11*).

IBM Type 705 EDPM

The type 705 electronic data-processing machine is a high-speed, general-purpose device of advanced design (*15*) (Fig. 3). The principal processing and input medium is magnetic oxide-coated plastic tape. A tape reel 2400 feet long, equivalent to from 25,000 to 50,000 punched cards, depending on arrangement, can be read into the system in about 6.5 minutes. This magnetic input tape can be prepared from punched cards or from punched-paper tape, with information in alphabetic, numeric, or symbolic characters. Internally the system utilizes magnetic core memory and, optionally, magnetic drum storage for high-speed access and processing. Adequate logical operations are provided, and programming can supply almost any imaginable complexity.

A special device makes it necessary to

compare only a preselected part of any unit record on the tape with similar control data in the 705 storage. Thus it would not be necessary to compare fully items that obviously did not fit requirements. In scientific information searching, this would increase the speed of the operation, provided that coding and classification or indexing were properly done. More is said on this later.

Output onto magnetic tape is at the same rate as input, 15,000 characters per minute. A device is available which will "print" data at the rate of 1000 60-character lines per minute. Other forms of output, such as punched cards, are also available.

It is obvious that this system has the characteristics that were specified for search and retrieval devices. It is an expensive data processor, but some measure of its value in business applications can be learned from the fact that more than 150 of these systems were on order at mid-year, 1956, and a score had been delivered.

UNIVAC File-Computer

A medium-size, general-purpose computer that is also of potential interest in scientific data processing is the UNIVAC File-Computer (*16*). This system has a more flexible input, in that it will accept data directly from electric typewriters and other key-actuated machines in addition to magnetic tape, perforated paper tape, or punched cards. Input speeds will vary accordingly, but magnetic tape is still the fastest input, about 6000 characters per second.

All internal storage is on a variety of magnetic drums, assuring fast access time, given proper coding. Two methods of programming are available: stored program and external panel control. Output may be in the form of magnetic or perforated tapes, punched cards, or various printers. Although this machine is slower and smaller than the 705 and is correspondingly cheaper, it does possess the desiderata for literature searching that are mentioned in foregoing paragraphs.

These and other devices are in existence now and could be used today for the purposes I have discussed. It seems likely that they will increase in speed and capacity as new models appear, in a way similar to past development. But what of the future for new types?

A machine for reading printed matter directly off the page is currently under development in several laboratories (*17*). This would enable us to deal efficiently with the vast printed record of science by eliminating more keyboard work before printed material was ready for data processing.

Much more difficult problems remain before a speech typewriter is perfected, although it too is actively being investigated (*18*). Such a tool could revolutionize our primary methods of preparing scientific data.

Indexing and Classification

Inventory entries on a magnetic tape must be tagged in such a way that the ones which match question data in the computer are "recognized." Once the matching is done, program steps can assure the correct output of the information. Such tagging or coding, when one is dealing with scientific information, immediately raises questions of classification and indexing. These, properly, are not a part of IDP or EDP, but it may be well to indicate some current work that seems likely to be of value.

Scientists in this country have not, in general, been satisfied with large-scale classification or marshaling schemes, such as the Universal Decimal Classification or the Library of Congress Classification. Instead, efforts to extend bibliographic control to scientific materials have largely turned to indexing techniques.

The main limitation of the latter is the fixed array imposed by the alphabet on an index. The white pages of a telephone directory are a good example. Another limitation, that of space, ordinarily precludes all permutations of a multiple subject heading from being entered. For instance, "Electromagnetic-waves-propagation-equations" can be arranged in 63 other orders, many of them significant, and in the majority of lists only one permutation would be used.

A technique for dealing with these problems has been proposed and used as the Uniterm system of coordinate indexing (*19*). Briefly, the method consists in assigning to each document or unit record a unique serial number and characterizing the contents of the document by means of words, the uniterms. The document number is entered on each card bearing one of the uniterms; in our example the number for a document would be entered on four separate cards. To select documents dealing with these four topics, it would be necessary only to scan the four cards for common document numbers. In actual installations, all this matching is now done by hand, I believe, but note that the technique is one that would lend itself easily to machine processing. As such it should be investigated for scientific applications of EDP.

Another system, which starts from different premises, is largely the work of J. W. Perry and his associates (*20*). His concern begins with the problems of language, and he has minutely analyzed thousands of scientific terms into "semantic factors." Thus, a pyrometer is a "temperature-measuring device," as is a thermometer. This analysis and a concern for the logic of classes led him more directly to a consideration of machine handling of scientific data. His final product in the system, an encoded, telegraphic-style abstract, becomes an item particularly amenable to machine manipulation.

These two examples are representative of work that is being done on the problems of indexing and classification (*21*). The fact that most of it occurs in science and technology stems, I believe, from the dissatisfaction that scientists have experienced with existing methods in these areas.

Some Related Current Work

I know of only one integrated system at present that utilizes the approach under discussion in dealing with scientific data. It exists at the Lewis Flight Propulsion Laboratory, Cleveland, Ohio (*22*). A wind tunnel is fitted with instruments which take readings of such parameters as speed, thrust, temperature, and fuel flow. The digital encoder translates these signals to binary code (in which the number 2 is the base) and records them on magnetic tape. From this the data can be reduced to usable form immediately or printed out for future study and reference.

With the large number of EDP machines going to industry for accounting work, it should not be long before some company with a research department finds that research reports can be "written" on the computer in a matter of minutes, and that, at the same time, storage of the data for future interrogation can be accomplished.

There are already a few other pioneer examples of computer uses near enough to our subject to be instructive. A book containing 1 million random digits has recently appeared (*23*). This was "composed" by a computer at the Rand Corporation specifically programmed to generate random numbers.

A series of 20,810 self-demarcating code words has been generated on an electronic data processor (*24*). These words, from *BAB* to *ZUZ* and from *BAAB* to *ZUUZ*, have the property that no two words in conjunction can make another word in the system by chance combination of letters. They thus eliminate the necessity for "word-stop" marks and thereby increase coding efficiency.

A most imaginative use of computers, similar to the foregoing example, has been the coining of "drugless names" by the thousands for Chas. Pfizer & Co. (*25*). A computer, again programmed in a special way, combined syllables to make

names for future drugs, thus neatly avoiding a tedious and formerly unsystematic task.

The Revised Standard Version of the Bible obviously requires a new concordance, and it was the happy thought of Reverend John W. Ellison that this be made with the aid of UNIVAC (*26*). Every word of the new Bible was entered, with its context, onto four reels of magnetic tape. By proper programming, the machine eliminated 132 frequently used short words (thus reducing the number of entries from 800,000 to 350,000) and then rearranged the words alphabetically. The output included the context and book, chapter, and verse.

The foregoing four examples have had outputs that would correspond to preparing compilations of scientific data and thus illustrate only that part of the process.

A meaningful and pertinent use of data handling for answering questions has recently been described by two chemists from the Dow Chemical Company (*27*). They have attacked an old problem in chemical literature searching: how to select chemicals having parts of structures in common. For instance, it may be required to select from an "inventory" of chemicals, stored on tape, all those containing two nitro groups, or those with three or more rings, or even chemicals having groups in a specified orientation to one another.

Using a specially designed code for chemical structure, and with the aid of a general-purpose, stored-program digital computer, Opler and Norton have been able to program a search on 1000 compounds that takes only a few seconds to complete. A manual on this program has appeared (*28*). The code for this experiment is of interest because it is derived from more general topological solutions, which have a bearing in searching circuit diagrams, maps, and the like (*29*).

It may also be of interest to record here that a mathematical model for integrated data systems has been proposed (*10*, p. 275).

Summary

This brief survey of integrated and electronic data processing has touched on such matters as the origin of the concepts, their use in business, machines that are available, indexing problems, and, finally, some scientific uses that surely foreshadow further development. The purpose of this has been to present for the consideration of scientists a point of view and some techniques which have had a phenomenal growth in the business world and to suggest that these are worth consideration in scientific data-handling problems (*30*).

To close, let me quote from William Bamert on the experience of the C. and O. Railroad once more (*8*, p. 121): "Frankly, we have been asked whether we weren't planning for Utopia—the implication being that everyone except starry-eyed visionaries knows that Utopia is unattainable. Our answer is that of course we are! Has anyone yet discovered a better way to *begin* program planning of this nature? Our feeling is that compromise comes early enough in the normal order of things."

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Cryogenic Instrumentation

J. G. Daunt

Progress in low-temperature technology has been associated with the development of methods of producing lower and lower temperatures. Milestones in this progress have been the successive achievements of the large-scale liquefaction of the so-called "permanent" gases, in particular air, hydrogen, and helium. It is now well over half a century that liquid air, as well as its important components liquid oxygen and liquid nitrogen, has been available. In this time the technology of liquid air temperatures has formed the basis for a multipurpose large-scale industry. Many plants operate today to produce liquid oxygen at rates of 120 tons per day (*1*), and the commercial needs for these low-temperature products continue to increase.

Production and Transportation of Low-Temperature Refrigerants

The development of the production of liquid hydrogen and liquid helium on a commercial basis, however, is relatively

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recent, and consequently the technology and instrumentation associated with these lower temperatures are today rapidly expanding. It is of interest to note that in September 1956 the second national Cryogenic Engineering Conference was held at the National Bureau of Standards Laboratories in Boulder, Colorado, and that this conference devoted a major fraction of its program to instrumentation for temperatures of liquid hydrogen and below.

The NBS Boulder Laboratories operate a large-scale hydrogen liquefaction plant capable of producing more than 300 liters per hour. A brief description of this equipment was published in October 1953 (*2*). The same liquefier when run with helium gas (although only at two-thirds capacity) produced 120 liters of liquid helium per hour (*3*). Collins now has a helium and/or hydrogen liquefier in operation in his laboratory at Massachusetts Institute of Technology which produces either 50 liters per hour of liquid hydrogen or about 45 liters per hour of liquid helium (*4*).

The uses to which this increasingly large-scale production of liquid hydrogen and liquid helium are being put are manifold, and consequently transportation of the refrigerants over long distances is becoming increasingly common and necessary. In this regard, one may note that recently a liquid helium service has been established in England by the National Physical Laboratory which provides many universities with this refrigerant on a commercial basis. The institution of a similar service in the U.S.A. is long overdue.

Looking beyond the relatively modest needs of research institutions for a liquid helium service, a study has been made by Scott and his staff at the NBS Boulder Laboratories of the feasibility of transporting helium in large quantities as a liquid rather than as a high-pressure gas, as is now done. They have estimated that a plant producing 400 liters of liquid helium per hour would allow its transportation as a liquid to compete economically with present rates (*3*). A similar conclusion has been arrived at by Collins (*4*), who considers it possible to reduce the cost of liquefying both hydrogen and helium to a figure only slightly greater than the cost of liquefying air.

Some of the newer and developing uses of liquid hydrogen are, for example, the separation of the hydrogen isotopes by distillation, the cooling of very high field electromagnets, and as the working liquid in large bubble chambers. The development of liquid helium bubble chambers is a new aspect of very low temperature instrumentation. A brief outline of these relatively new instrumental developments in cryogenics follows.

Separation of Hydrogen Isotopes by Distillation

The pioneer work of Urey, Brickwedde, and Murphy (*5*) on the enrichment of deuterium was by a distillation process. Subsequently small-scale separations by distillation have been carried out by Keesom and coworkers (*6*), Brickwedde and Scott (*7*), and Clusius and Starke (*8*). The latter work was done in 1941–42 but was not published until 1949, at which time the commercial importance of heavy water for power reactors emphasized its significance. Large-scale distillation separation of deuterium is economically significant only if by this technique the price of D_2O can be reduced well below that of other more usual methods of heavy water production (*3, 9*). In fact, the distillation process looks economically very advantageous, as was pointed out by Clusius and Starke (*8*), who computed that D_2O could be produced by this process for 4.8 kilowatt hour per gram as compared with 120 to 150 kilowatt hour per gram by the electrolysis of water (*10*).

The Clusius-Starke process for the large-scale separation of deuterium proposed fractionating natural hydrogen, which has about 0.028 percent HD content, in a primary rectifying column at about 20°K, so that the top of the column would be essentially HD free and the bottom would have 5 to 10 percent HD content. The HD-rich liquid would then pass to the top half of a secondary fractionating column, from the bottom of which nearly pure HD would be extracted. This HD, after passing through heat interchangers, would be converted at room temperature by a catalyst so that the reaction $2HD \rightleftharpoons H_2 + D_2$ would take place. The reacted product, $H_2 + HD + D_2$, would be fed back, by way of the heat exchanger, to the lower half of the secondary fractionating column, from the bottom of which pure deuterium could be drawn off. The flow diagram is given in Fig. 1.

Plants, using processes similar to the one just described, were designed in 1950 by Hydrocarbon Research, Inc. (*11*) in the U.S.A. for liquid hydrogen distillation to produce 34 tons of D_2O per year, and plans have been made by Linde-Gesellschaft in Germany (*12*) for the production by distillation of 6 tons of

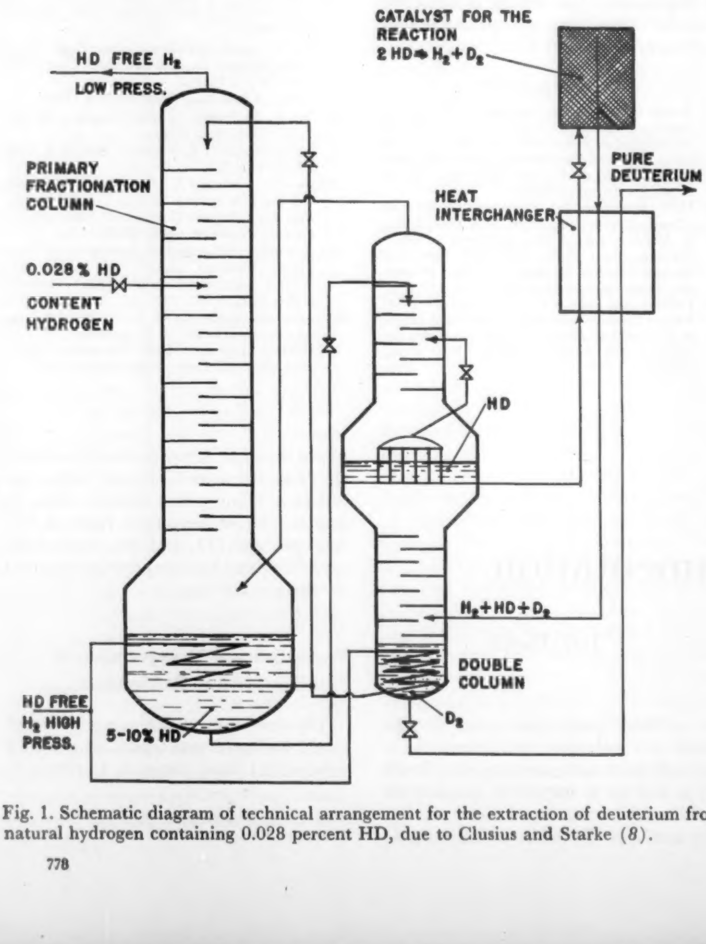

Fig. 1. Schematic diagram of technical arrangement for the extraction of deuterium from natural hydrogen containing 0.028 percent HD, due to Clusius and Starke (*8*).

D_2O per year and by Le Societe l'Air Liquide (*13*) in Toulouse, France, for 2.5 tons per year. The latter two plants are to be located at large synthetic ammonia plants, so that the raw hydrogen can be "borrowed," stripped of its deuterium, and then returned.

The problems involved in the detailed designs of such plants are peculiar to the unusually low temperatures and to the characteristics of the material being processed, and experimental work on such problems has recently been reported (*14*) by the NBS Cryogenic Engineering Laboratory at Boulder, in particular concerning the efficiency of various types of plates for use in the fractionating columns.

Liquid Hydrogen-Cooled Electromagnets

By cooling the windings of electromagnets with refrigerant liquids, a considerable gain in the power consumption for a given magnetic field times volume product can be achieved. Liquid nitrogen-cooled solenoid magnets have been operated by Collins (*15*) and by Fritz and coworkers (*16*). In the hollow cylindrical core of such a magnet, the core being 2⅛ inches in diameter and 4 inches long, a field of 22 kilogauss could be maintained with a power dissipation of 15.3 kilowatts and a liquid nitrogen consumption of 5.7 liters per minute (*15*).

Liquid hydrogen-cooled solenoids have been developed at the Los Alamos Scientific Laboratory, and a recent report by Laquer (*17*) states that a wire-spaced "jelly roll" type solenoidal magnet, 5 inches long, 2½ inches inside diameter, and 7½ inches outside diameter, maintains a field of 65 kilogauss for a dissipation of 15 kilowatts when it is cooled by "freshly boiling hydrogen." This corresponds to an evaporation of 28.2 liters of liquid hydrogen per minute. Where liquid hydrogen is available in very large quantities, this offers a significant method of attaining intense magnetic fields with minimum power requirements.

Liquid Hydrogen and Liquid Helium Bubble Chambers

The bubble chamber, introduced by Glazer (*18*), like the Wilson cloud chamber, detects tracks of ionizing particles. The chamber is filled with a suitable liquid which is brought into a superheated state by rapid expansion. Ionizing particles passing through the liquid produce centers of nucleation for the boiling of the liquid and produce a "bubble" track. One of the most useful liquids for such bubble chambers is liquid hydrogen, since nuclear events involving protons are of particular significance. As is pointed out by Hildebrand and Nagle (*19*), who first reported the construction of a liquid hydrogen bubble chamber at Chicago University, it provides "a hydrogen target of greater density and purity than can be achieved in a cloud chamber."

For successful operation, the chambers must be maintained at about one-half of the critical pressure of the liquid before the expansion takes place: low boiling point liquids, with their correspondingly low critical pressures, allow small operating pressures to be employed. In liquid hydrogen bubble chambers, pressures of about 5 atmospheres are usually employed; and in the helium bubble chambers, first developed by Fairbank and coworkers at Duke University (*20*), atmospheric pressure is used, which technically is very advantageous. In the hydrogen bubble chamber being developed by the NBS Cryogenic Laboratory and the University of California Radiation Laboratory (*3*), the operating pressure and temperature are 5 atmospheres and 27°K, respectively; that is, the liquid hydrogen is subcooled. The expansion suddenly reduces the pressure to 2 atmospheres and, after a time of approximately 2 milliseconds, the bubble tracks are photographed.

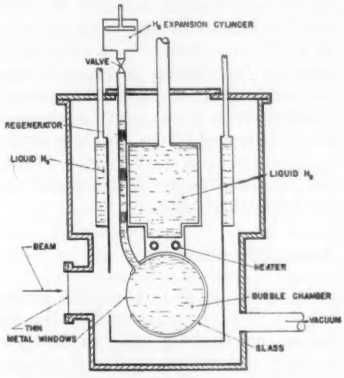

Fig. 2. Schematic diagram of liquid hydrogen bubble chamber, due to R. B. Scott. The expansion is effected by expanding the vapor through the valve into the expansion cylinder. [Drawing from W. Meissner, *Z. Kältetechnik.* 8, 34 (1956)]

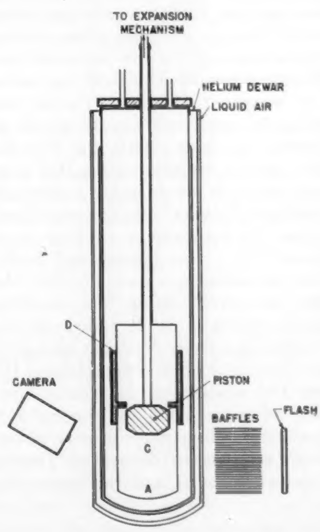

Fig. 3. Diagram of liquid He^4 bubble chamber, due to Harth, Fairbank, Blevins, and Slaughter (*20*). The expansion is effected by an upward movement of the piston, which is in direct contact with the surface of the liquid. The piston is of Teflon and slides in a close-fitting Teflon sleeve.

The expansion of the liquid in the chamber can be achieved either by rapid expansion of the vapor above it, as is shown in the liquid hydrogen design of Fig. 2, or by actual expansion of the liquid itself, as is shown in the liquid helium arrangement of Fig. 3, which is designed to have a 1.01 expansion ratio.

A liquid hydrogen bubble chamber 10 inches in diameter and 6½ inches in depth with an active volume of 8 liters has been put into operation at the University of California Radiation Laboratory (*21*), and it is located in a magnetic field of 12-kilogauss intensity. A still larger one for use with the 6-Bev accelerator, having a glass window 20 by 72 inches and a volume of approximately 500 liters, is being designed by the University of California Radiation Laboratory and the NBS Cryogenic Engineering Laboratory (*3, 22*).

The liquid helium bubble chambers at present being designed are more modest in size; Fairbank *et al.* (*23*) are reporting now on chambers 8 by 5 by 4 inches.

Magnetic Refrigerator

To obtain temperatures below 1°K, the well-established method of magnetic cooling first proposed in 1926 independently by Giauque (*24*) and Debye (*25*) has been in use since 1933. This method makes use of the magneto-caloric effect in paramagnetic substances, which, when they are adiabatically demagnetized, suffer a temperature drop. Starting at initial temperatures of about 1°K, temperatures as low as a few millidegrees can be reached within suitable paramagnetic salts. The paramagnetic cooling substance, together with such experimental arrangements as may be in thermal contact with it, after attaining the low temperature suffers continually thereafter a steady heat influx from its surroundings. The final end temperature of the process

is that of the surrounding liquid helium bath.

Recently a cyclic system of magnetic cooling has been devised by Daunt and Heer (*26*) which can maintain a reservoir *continuously* at temperatures below 1°K. In our first working model of this cyclic system (*27*) temperatures as low as 0.25°K could be continuously maintained (*28, 29*). Its operation can be followed from the diagram of Fig. 4. Here the paramagnetic salt A is the working substance, suspended in a vacuum chamber that is immersed in a liquid helium bath at about 1°K. The working substance is connected thermally, on the one hand, to the bath by way of the thermal valve V_1, which is in the form of a thin lead ribbon soldered to copper supports E, and, on the other hand, by way of a similar thermal valve V_2, to the reservoir R, which is to be continuously refrigerated. The thermal valves, which can be made to allow or almost prevent the flow of heat through them, depend for their action on the fact that pure superconducting substances such as lead, at temperatures well below their transition temperatures, have a thermal conductivity in their super state much smaller than that in their normal state (*30*). The transition from super to normal state can be made reversible by the application of a small magnetic field (for the lead thermal valves, switching fields of about 800 gauss are used), and hence by application or removal of this magnetic field the lead strip can be made either a thermal conductor or a thermal insulator. The operation of the cyclic refrigerator therefore consists in having valve V_1 "open" and V_2 "closed" when A is being magnetized, and on the demagnetization of A valve V_1 is closed and V_2 opened. During the demagnetization therefore the reservoir R can share in the cooling produced in A. The complete cycle, in which ferric alum as the working substance is magnetized in fields of about 7 kilogauss, is repeated every 2 minutes, the operation being controlled by the switching in correct succession of three magnetic fields, one for the working substance and two for the thermal valves.

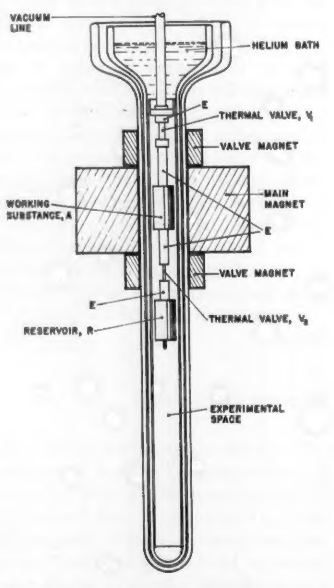

Fig. 4. General arrangement of the low-temperature parts of the magnetic refrigerator (*26, 27, 29*).

Thermal Rectifier

An interesting thermal rectifier for use below 1°K has been reported by Hwang, Fulton, and Fairbank (*31*). In their preliminary experiments they used a 3-percent solution of He^3 in He^4 located in a vertical stainless steel capillary 4 inches long and 0.017 inch inside diameter, the lower end of which was tied thermally to the temperature of a helium bath at about 1°K and the upper end supported a paramagnetic salt for magnetic cooling. They found that when the upper end was warmer than the lower end, heat flowed easily through the tube, whereas when the salt was cold the tube was an effective thermal insulator. This rectifying action, they suggested, was due to the fact that when the upper end was the cooler, internal convection within the He^3 and He^4 solution would carry the He^3 to the top, where it would form a thermally insulating "pocket." On the other hand, when the temperature gradient is reversed there is no gravitational preference for collecting a pocket of He^3 from the convective process. The rectifying action therefore is dependent on the gravitational field. A similar strong dependence of the heat conductivity of He^3 and He^4 solutions on the relative directions of gravitational and thermal field gradients has been noted in work on very dilute solutions by Beenakker, Taconis, Lyndon, Dokoupil, and van Soest (*32*).

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Fixed-Field Alternating-Gradient Accelerators

L. Jackson Laslett

Developments in the art of designing high-energy particle accelerators may be of interest not only to nuclear physicists but also to those working in chemical and engineering fields, to biologists, and to workers engaged in medical research. For the physicist, the possibility of studying particle reactions at increasingly *high energies* may be the most exciting aspect of such developments, although a substantial increase of *intensity*, at energies presently available, would make possible definitive experiments that are now difficult to perform. For production of radiation effects on matter *en gros*, as in the production of cross-linkages in polymers or in various investigations of radiation damage, intensity may be the more important characteristic of an accelerator. In the present article (*1*), I attempt to outline a potential new development in the accelerator art which appears to offer not only the prospect of certain engineering advantages but also the promise of a substantial increase of intensity or of the energy available for the study of particle reactions. Analysis of the particle orbits to be expected in the proposed structures affords a number of important and challenging mathematical problems concerning which, it may be hoped, an improved analytic understanding will be built up to supplement results obtained by digital computation.

The developments discussed here are the result of study by a group of midwestern physicists (*2*) who were stimulated by the broad class of new accelerators apparently made possible by the use of the alternating-gradient principle, which was first announced from the Brookhaven National Laboratory (*3*). Specifically, in contrast to the present Brookhaven efforts, the midwestern group has concentrated on a class of cyclic accelerators employing magnetic fields that are *constant* in time.

In any cyclic accelerator, such as the cyclotron, betatron, or synchrotron, a charged particle makes a great number of revolutions within the structure, gaining a relatively small amount of energy on each turn, and the provision of suitable focusing forces is essential. It may be of interest to note in this connection that, in a number of typical accelerators now in use, the distance covered by the particle during the acceleration process ranges from one-third of the distance across the United States to some 6 or 8 times around the earth. Since particles with energies that are at least slightly different will be simultaneously present, a related property of an annular accelerator of importance in its effect on the cost of the structure is the ability to accommodate particles with various energies within an annular region of limited radial extent.

If, as is customary, the particles are guided by a magnetic field as they follow their orbits around the accelerator, it is particularly convenient to achieve the requisite focusing by adjustment of the spatial variation of this field. In the case in which the fields show no variation with azimuth, a suitable index to characterize this spatial variation is

$$n \equiv \frac{r}{B}\frac{dB}{dr}$$

where r represents the distance from the central axis of the machine, and B represents the strength of the (axial) field in the median plane. In the absence of an azimuthal variation, stability in both the radial and axial directions is obtained only if the condition

$$-1 < n < 0$$

is satisfied. The energy or momentum content of such a machine is expressed by the quantity

$$\alpha \equiv \frac{r}{p}\frac{dp}{dr} = n + 1$$

where p denotes the particle momentum, and α is so small than an annular accelerator must then be operated in a pulsed manner to provide an increasing field adequate to hold particles of increasing energy within the machine.

In a conventional continuous-wave cyclotron, with the index n constrained to lie between 0 and -0.2 in order to avoid a coupling resonance between the radial and axial oscillations, the requirement that the frequency of revolution be independent of energy imposes a limitation on the attainable energy when the relativistic increase of mass becomes significant.

Description

A markedly greater energy content can be achieved in an annular accelerator if a rapid radial increase of the guide field is permitted by introduction of alternating-gradient focusing to maintain orbit stability. The field may then be capable of accommodating simultaneously particles of a wide range of energy, and the field strength could be independent of time. Such a modification, although it introduces complications associated with the significantly nonlinear character of the differential equations governing the particle motion, evidently promises a number of significant advantages.

1) Direct-current magnet construction and excitation may be employed.

2) The magnetic field need only be adjusted for operation at a single level of excitation, thus avoiding the difficulties associated with remanence, saturation, and eddy currents in a pulsed accelerator.

3) There is greater freedom in the choice of injection energy, and the time schedule for the acceleration process is flexible.

4) High intensity appears possible, owing to the permissible flexibility in planning the means of particle acceleration. Azimuthal variation of the field in a cyclotron, with the associated alternating-gradient focusing effects, can also be advantageous, because it allows higher energies to be reached than otherwise would be permitted by the relativistic increase of mass with energy.

In subsequent paragraphs I discuss a number of specific types of structures in which fixed-field alternating-gradient focusing is present (*4–6*). The structures are of two general types, one employing radial sectors and the other a spiral sector pattern. The first-mentioned type is in some ways simpler and easier to construct, while the second appears to permit a smaller accelerator for a given energy. In all the structures, particles with a wide range of energies can be simultaneously accommodated by virtue of a magnetic field whose average value around the machine varies with radius as r^k, and focusing forces leading to stable motion are obtained by a suitable spatial variation of the field.

The author is at present on leave of absence from Iowa State College to work at the University of Illinois as a member of the Technical Group of the Midwestern Universities Research Association. Some of the material on which this article is based was discussed at the International Conference on Accelerators in Geneva, Switzerland, during the week of 11 June and at a meeting of the Canadian Association of Physicists on 14 June 1956.

Reversed-Field Design

In the reversed-field type of fixed-field alternating-gradient (FFAG) accelerator, the direction of the field is reversed from one sector to the next. The sector boundaries are usually supposed to be formed by geometric planes that extend radially from the axis of the accelerator. The strength of the field in the reversed-field sectors, or the length of the reversed-field sectors, must, of course, be less than for the sectors of positive field in order that the particle orbits will ultimately be bent around through 360 degrees and permit a closed equilibrium orbit to be drawn (Fig. 1).

The magnitude of the field in the reversed-field accelerator varies at every azimuth as r^k, where r is the radius from the central axis of the machine. If k is positive, there is axial defocusing in the positive-field sectors and axial focusing in the reversed-field sectors. The alternating-gradient action is found to yield reasonable stability for small-amplitude oscillations in both the radial and axial directions, provided that the combined circumference of the forward and reversed-field magnets is some 5 times that required by an azimuthally constant magnetic field of the same maximum field strength. The ratio of the combined circumference to that required for a constant magnetic field is termed the *circumference factor*, C.

Within the individual sectors, the fields would normally be such that the complete equilibrium orbit would be formed from a series of circular arcs with their centers displaced from the axis of the machine. Denoting the radius of curvature of the orbit by ρ, the local focusing index is $n = k \cdot \rho/r$ and, if the same magnitude of field strength prevails in the positive and negative sectors, $\rho = r/C$. In linear approximation the radial and axial oscillations in such structures can then be expressed reasonably accurately, when the number of sectors is large, by the equations

$$\frac{d^2x}{d(s/r)^2} \pm kCx = 0$$

$$\frac{d^2z}{d(s/r)^2} \mp kCz = 0$$

where s denotes arc length along a reference circle of radius r, the upper and lower signs refer, respectively, to the sectors of positive and negative field, and centrifugal effects have been neglected since we assume that $kC \gg 1$. These equations may be solved by the aid of the matrix methods that are customarily employed in analysis of alternating-gradient focusing. If the phase change per sector for the radial oscillations and the corresponding phase change for the axial oscillations are permitted to assume widely different values, lying near the upper and lower limits of the stable range, a design with C as low as 5 may be feasible. A more accurate calculation must, of course, take account of the edge effects that arise at the sector boundaries and would involve an expansion about an equilibrium orbit which, accordingly, must be determined first. For a complete account of the motion, the effect of nonlinear terms would also have to be included.

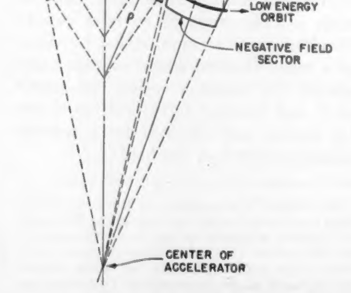

Fig. 1. Orbits in a reversed-field FFAG accelerator.

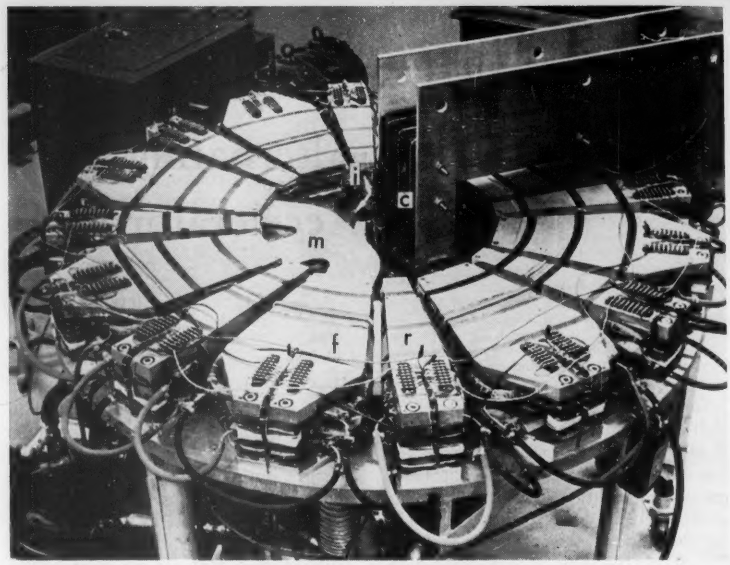

Fig. 2. An operating electron model of a reversed-field FFAG accelerator. Eight sectors of positive field and eight narrower sectors of negative field are employed. The betatron core is seen linking the region occupied by the particle orbits. (*f*) Magnet sector with forward or positive field; (*r*) magnet sector with reversed or negative field; (*c*) betatron core; (*i*) injector; (*m*) pump manifold.

Attention is directed to the important scaling property of the orbits in this accelerator. Possible orbits of particles of different energies, or momenta, are scaled replicas of each other. In consequence, the frequencies of the oscillations will be independent of energy, and harmful resonances may be avoided at all energies by a consistent design. The momentum content is represented by $p \propto r^{k+1}$, so that the momentum compaction factor α is given by

$$\alpha = k + 1$$

and can be either positive or negative in a reversed-field accelerator.

A small working model of a reversed-field FFAG accelerator has been put into operation (7). This model, shown in Fig. 2, employs eight sectors of positive field and eight shorter sectors of negative field. Electrons are accelerated, at present by betatron action, from 25 kev to 400 kev. Tuning controls have been provided for the model, so that various oscillation frequencies can be produced. These frequencies can be measured accurately by a radio-frequency knock-out technique (8) and the effect of certain resonances on the beam noted. The model affords an opportunity to study operation with a high duty factor, as is possible in FFAG accelerators employing betatron acceleration. Radio-frequency acceleration methods will also be investigated.

Possible parameters for a large-scale reversed-field FFAG accelerator for the production of 10 Bev protons have been examined. Although such a machine would be expected to have many desir-

able characteristics, the large magnet mass and power requirements direct interest to other FFAG designs of smaller circumference factor. By virtue of its essential simplicity, however, the reversed-field type may remain of interest for accelerators of low or intermediate energy, especially if a high duty factor can be efficiently realized with betatron acceleration.

Spiral-Sector Design

To avoid the considerable circumference required for a reversed-field FFAG accelerator, an alternative arrangement has been suggested by D. W. Kerst and others of the Midwestern Universities Research Association (MURA) group in which the alternating-gradient action is provided by a smaller but more rapid spatial variation of the field, the field being alternatively high and low along spiral curves which all particles must cross. Illustrative of the type of field present in the median plane of such a structure, one may take

$$B_{z_0} = \langle B \rangle (r/r_0)^k \left\{1 + f \sin\left[\frac{\ln(r/r_0)}{w} - N\Phi\right]\right\}$$

From this expression it is seen that N is the number of spiraling ridges passed over by a particle in going around the machine once. The coefficient f is the fractional flutter in the magnetic field owing to the ridges. Finally, if the radial width of the annulus is small in comparison with the outer radius, r_0, $\lambda \cong 2\pi r_0 w$ is substantially the radial separation of the ridges. The exponent k is taken to be positive.

In the spiral-sector design, as in the radial-sector case, the fields and the orbits satisfy the scaling condition. In passing from one energy to another, there is, however, a *rotation* of the geometrically similar orbits, which presents complications if one wishes to introduce straight-sections (field-free regions) whose boundaries extend radially from the central axis of the machine.

The equilibrium orbit in the spiral-sector machine departs from a circle by an amount that affects significantly the character of the small-amplitude oscillations. For analytic work (*9*) it is appropriate to expand the equations of motion about the scalloped equilibrium orbit. In terms of cylindrical coordinates (r, z, θ) we introduce the notation

$$x \equiv \frac{r - r_1}{r_1}$$

$$y \equiv \frac{z}{r_1}$$

$$N\theta \equiv N\Phi - \frac{1}{w}\ln(r_1/r_0)$$

and choose r_1 so that the dimensionless variable x will be small. The forced motion that produces the noncircular equilibrium orbit is found to be quite well represented by

$$x_f = -\frac{f}{N^2 - (k+1)} \sin N\theta$$

and the linearized equations describing small-amplitude oscillations are represented by Hill equations of substantially the following form:

$$u'' + (a_u + b_u \cos N\theta + c_u \cos 2N\theta)\, u = 0$$

$$y'' + (a_y + b_y \cos N\theta + c_y \cos 2N\theta)\, y = 0$$

where

$$u \equiv x - x_f$$

$$a_u \cong k + 1 - \tfrac{1}{2}\frac{(f/w)^2}{N^2 - (k+1)}$$

$$b_u \cong \frac{f}{w}$$

$$c_u \cong \tfrac{1}{2}\left(\frac{f}{wN}\right)^2$$

$$a_y \cong -k + \tfrac{1}{2}\frac{(f/w)^2}{N^2 - (k+1)}$$

$$b_y \cong -\frac{f}{w}$$

$$c_y \cong -\tfrac{1}{2}\left(\frac{f}{wN}\right)^2$$

Nonlinear terms in the equations of motion can also be obtained.

The frequencies and other characteristics of the oscillations characterized by the foregoing linear equations can be obtained by the use of tables prepared with the aid of the electronic digital computer of the Graduate College of the University of Illinois (ILLIAC). Useful orientation is provided, however, by writing the frequencies that are given by a simple approximate solution (*10*), ignoring the relatively small effect of the terms involving $\cos 2N\theta$ and taking $N^2 \gg k+1$:

$$\nu_x = [k+1]^{1/2}$$

$$\nu_y = \left[\left(\frac{f}{wN}\right)^2 - k\right]^{1/2}$$

It is thus seen that the frequency of the free radial oscillations is substantially determined by the exponent k characterizing the radial increase of average field strength, so that $k+1$ must be positive, and that axial stability may be obtained if the term $(f/wN)^2$ is sufficiently large to dominate $-k$. The stability region for the small-amplitude oscillations represented by the Hill equations cited has been mapped by aid of the ILLIAC tables and is depicted in Fig. 3.

The nonlinearities associated with large-amplitude motion in the spiral-sector accelerator make the use of automatic digital computation particularly helpful in trajectory studies. Results pertaining to motion with 1 degree of freedom are appropriately and conveniently represented by phase plots that depict the position and associated momentum of a particle as it progresses through successive "sectors" (periods of the structure) from one homologous point to another (Fig. 4). For small-amplitude motion, the particle is represented by a point that moves around an elliptical curve in phase space, while, with larger amplitudes, curves departing from the elliptical shape may be followed. At still larger amplitudes, unstable fixed points—representing an unstable equilibrium orbit—make their appearance. Associated with the unstable fixed points, one finds a separatrix, constituting an effective stability limit to the motion, which in the majority of cases the ILLIAC results depict as a sharp boundary and outside of which it is frequently possible to draw the initial portion of unstable phase curves.

Because of the nonlinear character of the oscillations, it is not surprising (*11*, *12*) that the permissible amplitude of oscillation is much curtailed if σ, the phase change per sector, lies near $2\pi/3$ or $2\pi/4$. It has, in fact, also been found (*13*) that the amplitude limit is reduced,

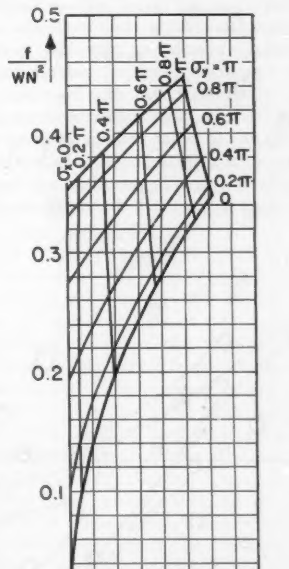

Fig. 3. First stability region ($0 < \sigma \equiv 2\pi\nu/N < \pi$) for small-amplitude oscillations in spiral-sector FFAG accelerators. The curves are calculated for the case $k \gg 1$ and are believed to be the most accurate for ordinates less than $\tfrac{1}{3}$. When the condition $k \gg 1$ is not satisfied, the diagram can best be used by entering at the point (k/N^2, f/wN^2) and proceeding up a curve of constant σ_y until an abscissa of $(k+1)/N^2$ is reached.

although not to zero, for $\sigma = 2\pi/5$. For cases in which σ_x is near $2\pi/3$, the limit of radial stability is characterized by the appearance of three unstable fixed points. In this case, an examination of the nonlinear differential equation for the trajectory permits a rough estimate to be made of the limiting amplitude (*14*):

$$A_x \cong 2(w^2N^2/f)\,|(\sigma_x/\pi)^2 - (2/3)^2|$$

It may be noted that, since the oscillation frequencies are essentially determined by k and f/wN, this formula suggests that a desirable increase of stable amplitude might be expected if f and w were each increased by the same factor.

Introduction of axial motion into a study of spiral-sector accelerators produces complications for all but the smallest amplitude oscillations, since there is coupling between this motion and that occurring in the radial direction. Surveys can be made, however, to determine the initial conditions that appear to exhibit short-time stability. In typical cases the permissible amplitude for axial motion appears to be materially smaller, possibly by a factor of 5, that is allowable for the radial motion. When oscillations in 2 degrees of freedom are treated, the characteristics of the axial motion and inferences concerning stability limits are materially affected by proximity to certain coupling resonances, notably those for which $\sigma_x = 2\sigma_y$, $\sigma_x + 2\sigma_y = 2\pi$, or $2\sigma_x + 2\sigma_y = 2\pi$. Near such resonances the amplitude of axial motion exhibits an exponential increase, over a considerable amplitude range, the rate of growth being the greater, the more the radial amplitude exceeds a certain threshold value, and the closer one is to the resonance in question. Some quantitative success in accounting for the growth of axial amplitude can be obtained by treating the differential equation for the axial motion as linear and inserting a prescribed expression for the radial oscillations into certain coupling terms that are linear in the axial coordinate.

In an actual accelerator, the N individual sectors will not be exactly identical, owing to the presence of unavoidable small differences in construction, excitation, or alignment. The basic period of the structure will thus be strictly N sectors, representing the machine as a whole, and additional resonances based on values of $N\sigma$ may be of importance. Computational study of the effect of realistic misalignments can be very informative prior to the fixing of specifications of a proposed machine. By way of example, studies of a proposed five-sector model ($\nu_x = 1.41$, $\nu_y = 0.87$) indicated that an axial displacement of one sector by 1/300 of the radius effected a reduction of the stable radial and axial amplitudes by factors of about 2 and 3, respectively.

Separated-Sector Modification

In the spiral-sector accelerator discussed in the foregoing paragraphs, an unnecessary and probably undesirable limitation was introduced by requiring that the field in the median plane have a precisely sinusoidal variation. The aperture that is magnetostatically possible is

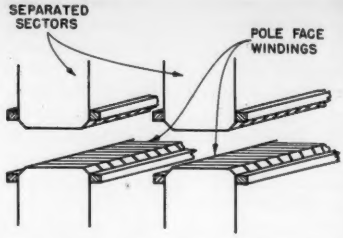

Fig. 5. Pole configuration illustrative of the separated-sector modification of a spiral-sector magnet. The currents carried by the pole-face windings are instrumental in achieving the r^k dependence of the magnetic field.

severely limited (*15*), especially if f differs markedly from the value ¼. In addition, the angle $\tan^{-1} Nw$ of the ridges (measured with respect to a reference circle) may be inconveniently small in a large machine, and a convenient construction may be difficult to realize. Attention is accordingly directed to structures involving separated poles (Fig. 5), a design that affords improved accessibility to the vacuum chamber and beam, easy realization of a more generous magnet gap, a considerably higher value for the root-mean-square field flutter, and a corresponding increase of the spiral angle. In this design it would be important to retain the scaling feature of the field and to take note of the high-order Fourier components that some pole configurations may introduce into the field. Retention of the scaling requirement makes it possible to solve the magnetostatic problem, which is defined by a specified pole contour, by relaxation methods on a *two-dimensional* grid which represents variables conveniently taken as

$$\xi \equiv \frac{1}{2\pi}\left[\frac{\ln(1+x)}{w} - N\theta\right]$$

$$\eta \equiv \frac{\sqrt{1+(wN)^2}}{2\pi w}\,\frac{y}{1+x}$$

The result of such computations may then be stored, again on a two-dimensional grid, for use in trajectory computations (*16*).

Plans are being completed for the construction, at the University of Illinois, of electron models that will provide experience pertaining to spiral-sector and separated-sector FFAG accelerators. These models will be similar in size to the reversed-field model mentioned in a previous section and likewise will employ betatron acceleration in the initial tests. Provisional designs of a large-scale machine have been attempted. It has been estimated that a separated-sector FFAG magnet for the production of 15-Bev protons would weigh about 12,000 tons and consume some 5 megawatts of electric power. This estimated magnet weight

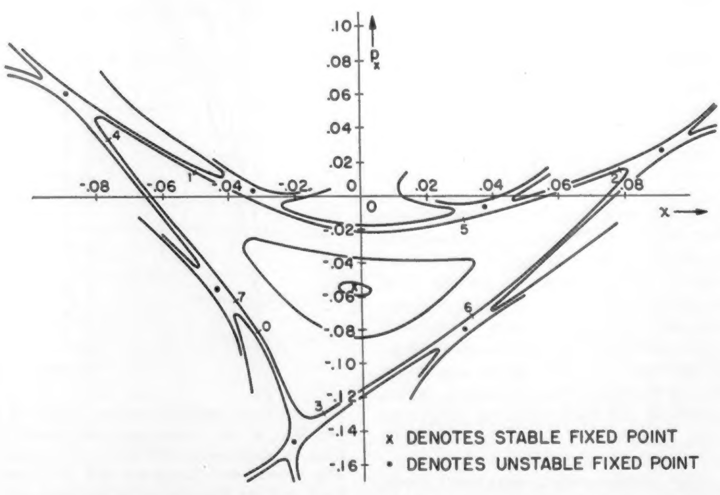

Fig. 4. Phase plot representing radial motion, at $N\theta = 0$ *mod.* 2π, in a spiral-sector FFAG accelerator. The machine parameters are those of a proposed model, for which $k = 0.8$, $1/w = 23.0$, $f = ¼$, and $N = 5$. In this case σ_x is close to 0.571π for small-amplitude motion. The value of σ_x does not change greatly with increasing amplitude, and it is noteworthy that ultimately ***seven*** unstable fixed points make their appearance in this particular example.

is intermediate between estimates that one would make for reversed-field and spiral-sector magnets, for which the estimated weights would be roughly 3 times greater or one-third as great, respectively. Although such a separated-sector structure may be some 6 times as massive as a pulsed accelerator of the same design energy, it may be felt that this feature is compensated to a considerable degree by the many simplifications which a direct-current design affords and that, as will be emphasized in a subsequent section, the increased freedom in detailed acceleration methods may permit a very significant increase of intensity.

Cyclotrons

It is attractive to consider the possible applicability of a spiral field variation to continuous-wave cyclotrons, as a generalization of the early suggestions of Thomas (*5*), in the interests of increasing the attainable energy. If, to permit continuous-wave operation, the frequency of revolution is to be independent of particle energy, the field index k that characterizes (differentially) the radial increase of the average field must satisfy the relationship

$$k+1=(E/E_0)^2$$

where E and E_0 are, respectively, the total energy and the rest energy of the particle. In a cyclotron, therefore, k must increase with energy, the oscillations will not satisfy the scaling requirement, and the possibility of encountering dangerous resonances during the acceleration process must be carefully considered. If we regard the relationship $\nu_x=[k+1]^{1/2}$ as sufficiently accurate for the present purpose, then $\nu_x \cong E/E_0$, the first half-integral and integral machine resonances for the radial motion ($\nu_x = 3/2$ and $\nu_x = 2$) would be encountered at kinetic energies of $\frac{1}{2}E_0$ and E_0, respectively (*17*), and the $\sigma_x = 2\pi/3$ inherent resonance at $[N/3-1]E_0$. The design of FFAG cyclotrons is currently being pursued by a number of groups, and design modifications that hold the promise of ameliorating the foregoing difficulties are being explored.

Acceleration Methods

In small-size annular accelerators that employ the FFAG principle, the use of betatron acceleration is highly attractive from the standpoint of intensity. If charged particles are injected into the gap of the fixed-field magnet during a substantial portion of the time the central flux is rising, they may be accelerated and arrive at the target with full energy so long as the flux continues to rise (Fig. 6). If the total change of flux within the core is twice that required to accelerate the beam from the low to the high magnetic-field region, the duty cycle would approach 25 percent.

For larger machines, radio-frequency acceleration methods would appear to be more practicable. The lack of dependence on a fixed magnet excitation cycle may permit in the FFAG accelerators a more rapid recycling of the radio-frequency program and a desirable flexibility in the design of this program. In analyzing the synchrotron motion, it is noteworthy that, in distinction to pulsed machines, the orbit radius and revolution frequency are a function only of the particle energy rather than of energy and time. To study in detail the effects of radio-frequency handling systems, it is helpful to employ a Hamiltonian theory for the synchrotron oscillations, in order that general theorems such as that of Liouville may be brought to bear on the problem. With $\omega(E)$ denoting 2π times the revolution frequency of the particle and E the energy, suitable canonical coordinates are the electric phase-angle ϕ with which the particle crosses the acceleration gap and the quantity w, related to energy, defined as

$$w \equiv \int^E \frac{dE}{\omega(E)}$$

For a single cavity of peak voltage V, frequency $\nu/2\pi$, and operating at the hth harmonic of the nominal particle frequency, the equations characterizing the synchrotron motion can then be derived from the Hamiltonian expression

$$\mathfrak{H} = V\cos\phi + 2\pi[\nu w - hE(w)]$$

in which V and ν are specified functions of time.

To avoid the large frequency swing—perhaps as great as a factor of 11—which would be required to carry a proton from its initial to its final energy in a single modulation cycle, it is attractive to think of raising the particle energy in a series of steps, each involving a comparatively small amount of frequency modulation. Such an arrangement provides a sort of "bucket-lift" process whereby groups of particles are simultaneously and progressively accelerated by means of a single radio-frequency source whose frequency is successively a smaller multiple of the increasing revolution frequency of the particle. If one commences with an oscillator frequency that is $s \cdot p^M$ times the rotation frequency of the injected particle and modulates by a factor p/q, the particle frequency is raised by this factor and the particle may be further accelerated in the $s \cdot q \cdot p^{M-1}$ harmonic during the next frequency-modulation cycle. The modulation cycle may thus be employed by the particle some $M+1$ times, as it progresses to higher energies, before synchronism is lost. The modulation factor p/q could be 3/2, for example, and a factor 2/1 might be particularly suitable.

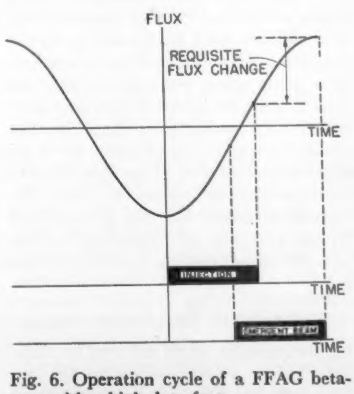

Fig. 6. Operation cycle of a FFAG betatron with a high duty factor.

If one thinks of using a bucket-lift process to stack particles at some intermediate energy prior to a final acceleration of the accumulated group by a second radio-frequency system, conservation of area in (ϕ,w) phase space tells us that the particles in successive buckets cannot be superposed exactly. Physically speaking, one group is slightly disturbed and displaced by the oscillator when it brings up a later group. This displacement has been studied computationally and is not sufficient to preclude the practicality of stacking a number of groups in a region of synchrotron phase space sufficiently limited that a second radio-frequency system could then accommodate them all.

For efficient stacking, it is of interest to ascertain the number of buckets that may be brought up empty at the end of the process. If $q=1$ and $p=2$, and if particles are injected only once per frequency-modulation cycle, the number of such empty buckets may readily be shown to be s, but these extra buckets can presumably be used with a consequent increase of intensity by more frequent injection.

There are several variants of this bucket-lift arrangement, which may present advantages chiefly of convenience. With an *unscheduled* bucket lift, particles not caught in a bucket at the onset of a particular frequency-modulation cycle will usually be displaced downward in energy by a passing bucket, but will be caught on occasional frequency-modulation cycles and in the end may be carried up in energy. The use of a completely stochastic acceleration method has been discussed in a Soviet paper (*18*) and shown to lead to acceleration of some particles by a sort of random-walk process.

It seems clear that the flexibility that fixed-field accelerators permit in regard

to design of particle-handling methods offers many promising possibilities. These possibilities are being further studied within the MURA group, chiefly by A. M. Sessler and K. R. Symon, both analytically and with the aid of digital computation. As a related endeavor, the characteristics of mechanically modulated radio-frequency cavities are being studied by Zaffarano and his associates at Iowa State College. The accumulation of intense beams within an accelerator or in adjacent storage rings (*19*), by a suitable stacking process may open the door to study of a new field of high-energy physics.

Intersecting-Beam Accelerators

With the possibility in sight of attaining beam intensities higher than have been possible heretofore, the opportunity arises (*20*) of studying high-energy particle interactions by directing one beam against another (Fig. 7). The outstanding advantage of such a system would be the large increase of effective center-of-mass energy which could be reached in this way. If two beams, each of energy E_1, are directed against each other, the total energy is, of course, $E_{CM} = 2E_1$. In contrast, a single beam of energy E_1' (measured in units of the rest energy) directed against a stationary target makes available a center-of-mass energy that is approximately $E_{CM} = (2E_1')^{1/2}$ for $E_1' \gg 1$. Thus two 15-Bev proton beams, oppositely directed, are equivalent to a single beam of 500 Bev directed against a stationary target, and two 21.6-Bev accelerators would be equivalent to one machine of 1 Tev (10^{12} ev).

In estimating the practicality of intersecting-beam accelerators, one must, of course, judge whether it is feasible to produce beam intensities that will result in a sufficiency large reaction rate. The interactions of interest must, moreover, be studied in the presence of background radiation produced by the individual beams and will bear a more favorable ratio to the background the greater the density of intersecting particles. In this regard, however, it may be noted that the background radiations will be confined to directions differing little from the beam direction, while the reactions of interest will be essentially isotropic in the laboratory system. The background and beam survival will be directly dependent on the degree of vacuum that can be maintained in the system; hence, recent developments for the realization of high pumping speeds (*21*) and the measurement of high vacuums (*22*) will be of importance. The additional focusing or defocusing effects that arise from space-charge forces, possibly modified by the effect of any electrons that may be captured by the beam, and the difficul-

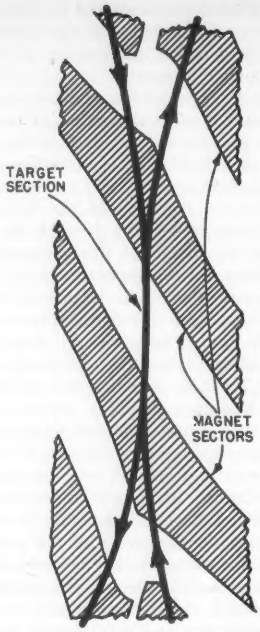

Fig. 7. Schematic method of effecting the intersection of high-energy beams. In the case illustrated, the individual accelerators are considered to be of the separated-sector type.

ties of handling safely a concentrated beam that may possess an energy of 1 megajoule will also require careful attention.

The intensities that one may be able to build up will certainly depend on the efficiency of stacking and on the ingenuity employed in the injection process. Although these techniques may be developed and improved as experience is gained with completed FFAG accelerators, an upper limit to the particle density in a stacked beam is imposed by Liouville's theorem. In regard to this limitation, we may estimate the number of injected pulses that theoretically could be assembled, after acceleration, in a region of reasonably small cross-sectional area. With respect to the energy spread associated with the motion in synchrotron phase space, we may consider the fate of particles injected with an energy spread ΔE_1, assuming for simplicity that synchrotron and betatron phase space are separately conserved. If the most efficient particle-handling system is used, the number of pulses that can be contained within a region ΔE_2 in energy at the completion of the acceleration process is

$$n_p = (\Delta E_2/\Delta E_1)/(\omega_2/\omega_1)$$

for $\Delta\phi$ constant, since the area in phase space is $\Delta\phi_2\Delta E_2/\omega_2 = n_p\Delta\phi_1\Delta E_1/\omega_1$. The quantity ΔE_2 in turn may be expressed conveniently in terms of the associated radial spread of the beam

$$\Delta E_2 = (k+1)(p_2^2c^2/E_2)(\Delta r_2/r_2)$$
$$\cong (k+1)E_2(\Delta r_2/r_2)$$

ultrarelativistically. Thus, if $k+1 = 100$, $E_2 = 15 \times 10^9$ ev, $\Delta r_2 = 0.5$ cm, $r_2 = 10^4$ cm, $\omega_2/\omega_1 = 11$, and $\Delta E_1 = 4 \times 10^3$ ev, we find that $\Delta E_2 = 7.5 \times 10^7$ ev and $n_p =$ 1700 particle pulses.

Similarly, in regard to the phase space for betatron oscillations, if the injector is imagined to scan the aperture, the number of horizontal and vertical scans that theoretically could be accommodated can be written

$$n_x = \frac{p_2}{p_1}\frac{(\Delta r_2)^2}{r_2\beta_x\Psi_x\Delta r_1}$$

$$n_y = \frac{p_2}{p_1}\frac{(\Delta z_2)^2}{r_2\beta_y\Psi_y\Delta z_1}$$

where Ψ_x, Ψ_y denote the angular spread of the injected beam, β_x, β_y relate the angular and linear displacements experienced during the course of a betatron oscillation ($\Delta r = r\beta_x\Psi_x$), and the momentum ratio p_2/p_1 accounts for the adiabatic damping of the oscillations. Accordingly, approximating $\beta_{x,y}$ by $2/\nu_{x,y}$,

$$n_xn_y = \left(\frac{p_2}{p_1}\right)^2 \frac{\nu_x\nu_y(\Delta r_2)^2(\Delta z_2)^2}{4r_2^2\Psi_x\Psi_y\Delta r_1\Delta r_2}$$

If we now substitute $p_2/p_1 = 100$, $\nu_x = 10$, $\nu_y = 5$, $r_2 = 10^4$ cm, $\Delta r_2 = \Delta z_2 = 0.5$ cm, and $\Psi_x\Delta r_1 = \Psi_y\Delta z_1 = 0.5 \times 10^{-3}$ radian cm, we find that $n_xn_y = 1250$.

This large value for the theoretically admissible number of scans implies a very complex scanning procedure and suggests that an injector with a much larger beam spread and correspondingly higher current would be desirable (*23*).

On the basis of the considerations of the preceding paragraphs, one would estimate that a 1-milliampere injector would permit the accumulation of

$$N_P = \frac{10^{-3}}{1.6 \times 10^{-19}} \times \frac{2\pi \times 10^4}{3 \times 10^{10}/11} \times 1700 \times 1250$$
$$\cong 3 \times 10^{17}$$

particles within a tube of about 1 square centimeter cross-sectional area. If we estimate that we actually may have 1/600 as large a beam as this, or 5×10^{14} particles circulating in each machine, some 10^7 interactions per second (proportional to N_P^2) may be expected to be produced in an interaction region that is 1 meter in length (*20*). With a vacuum of the order of 10^{-6} mm-Hg of nitrogen gas, the background produced in this target volume may be expected to be larger by about one order of magnitude, but, as is pointed out previously, the background radiations will be confined primarily to the median plane. Interaction with the residual gas also has the effect of limiting the beam life, possibly to a time not much longer

than 1000 seconds in the present example, so that groups of particles must be injected to replenish the beam at a rate not less than the reasonable value of one group per second.

It is the hope of the MURA group that further theoretical and experimental work will lead to the design and construction of models that will permit testing means for efficient particle acceleration, the investigation of high-current beams, and the eventual realization of a research machine that will take full advantage of the benefits to be derived from the FFAG principle.

References and Notes

1. It is impossible here to give explicit credit to the many physicists who have contributed to the development of these ideas, but it is fitting to indicate our special appreciation of the courtesy which the University of Illinois has extended to the MURA group in making the ILLIAC available for numerous computational studies and our indebtedness to J. N. Snyder for directing this phase of the program. I wish also to express my appreciation to D. W. Kerst, K. R. Symon, and A. M. Sessler for assistance in the preparation of this article and to K. Lark-Horovitz for his courtesy in reading the manuscript in draft form.
2. The technical group has been under the direction of D. W. Kerst. As the interest in the work grew, a number of midwestern institutions formalized this cooperative effort by forming the Midwestern University Research Association (MURA). The work of the technical group has been assisted by the National Science Foundation, the Office of Naval Research, and the U.S. Atomic Energy Commission.
3. E. D. Courant, M. S. Livingston, H. S. Snyder, *Phys. Rev.* **88**, 1190 (1952).
4. The interest of the midwestern group in fixed-field alternating-gradient (FFAG) accelerators arose from the original suggestions of K. R. Symon, made during meetings of the technical group in the summer of 1954. The idea of accelerators employing annular direct-current magnets was also proposed earlier, in at least one form, by T. Ohkawa at a meeting of the Physical Society of Japan and appears to have received brief consideration by others working in the accelerator field. A special form of cyclotron employing an azimuthal variation of field is the design proposed by Thomas (*5*).
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6. Discussion of FFAG accelerators has been given in papers presented before the American Physical Society and in a paper by K. R. Symon *et al.*, "Fixed-field alternating-gradient particle accelerators" (*Phys. Rev.*, in press), in which a general theory of orbits, applicable to a variety of types of cyclic accelerators, is derived in linear approximation.
7. The reversed-field model was constructed at the University of Michigan under the direction of K. M. Terwilliger and L. W. Jones. The magnet design was carried to completion by R. Haxby of Purdue University, and injectors were supplied from Kerst's laboratory at the University of Illinois. A substantial portion of the theoretical work was contributed by F. T. Cole of the State University of Iowa.
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11. J. Moser, *Nachr. Akad. Wiss. Göttingen Math.-physik Kl. IIa* 1955, No. 6, 87 (1955); *Commun. Pure and Appl. Math.* **8**, 409 (1955).
12. P. A. Sturrock, *Static and Dynamic Electron Optics* (Cambridge Univ. Press, Cambridge, 1955), chap. 7. In place of the quantity that I have denoted σ, Moser (*11*) employs $2\pi\omega$ or $2\pi a$, and Sturrock employs θ. My quantity σ may be related to the number of betatron oscillations, ν, executed by the particle as it passes through N sectors to make a complete circuit of the accelerator, by the relationship $N\sigma = 2\pi\nu$.
13. R. Christian, unpublished.
14. This relationship was derived originally by A. M. Sessler and me, and it has recently been treated more carefully by G. Parzen, unpublished.
15. In the absence of back-wound currents on the pole surface and with f assuming its optimum value, 0.24, the available magnet gap is limited to $G = 0.28(2\pi w)r = 0.28\lambda$, where λ is the radial wavelength of the magnet structure.
16. This computational method is outlined and certain useful general features of the fields are treated, respectively, in the following MURA reports: L. J. Laslett, *Proposed Method for Determining Mark V Trajectories by Aid of Grid Storage*, MURA-LJL-8 Rev. (1956); J. L. Powell, *Mark V FFAG Equations of Motion for Illiac Computation*, MURA-JLP-6 (1955).
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Sonic Techniques for Industry

T. F. Hueter

Recently an impressive gathering of acoustical scientists and engineers took place in Cambridge, Massachusetts. From 18 to 23 June, more than 800 experts from approximately 20 nations met at Massachusetts Institute of Technology and Harvard University to participate in the second International Congress on Acoustics. Five main themes had been selected for the technical program to represent the major fields of current activity in acoustics. Most of these dealt with more or less familiar problems, such as speech and hearing, sound reproduction and recording, noise control, and wave propagation. A group of five technical sessions, however, comprising about 50 papers, appeared under the collective heading of "Sonics." Most of these papers had very practical implications, the accent being on techniques and applications rather than on studies of acoustic phenomena for their own sake. Sound waves of all frequencies were shown to be useful as a tool in a variety of technical fields quite remote from the customary domain of classical acoustics.

Many participants in these sessions came from industrial laboratories or engineering centers, and it was apparent from the discussions that a new area of technology, based on the use of sound waves, is taking shape. About 2 years ago, R. H. Bolt of M.I.T. and I coined the term *sonics* for this new technology, which encompasses the analysis, testing, and processing of materials and products by the use of mechanical vibrating energy. The particular frequency that is best suited for a given task is determined by the special requirements and limitations of the task. All applications of sonics, however, are based on the same physical principles, and the relation of the frequency used to the range of audibility for man's ear is irrelevant from this point of view.

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Applications

We shall see that the phenomenon of acoustic vibration can be utilized in many ways. With sound waves we can "sonograph" (as with light waves we photograph) the inner structure of bodies that are opaque to light. Sound waves can penetrate many solids and liquids more readily than x-rays or other forms of electromagnetic energy. Thus sound can expose a tiny crack imbedded many feet deep in metal, where detection by any other means might be commercially impracticable if not impossible. Similarly, ultrasonic pulse techniques are now being used in medicine for the early diagnosis of abnormal tissue growths.

By acoustic techniques we can measure the elastic constants of solid materials, and residual stresses or structural changes can be analyzed. The molecular arrangements within many organic liquids can be inferred from measurements of sound velocity or absorption. The rates of energy transfer among gas molecules and the chemical affinity of gaseous mixtures can be determined by using sound waves.

As soon as we can measure a process, we have within reach a means of controlling it. Indeed, acoustic instrumentation offers extensive but virtually unexplored opportunities in the automatic control of industrial processes. The geometry of metal parts, the quality of cast metals and laminated plastics, the temperature in the combustion chamber of gasoline engines, the composition of compounds in the liquid or gas phase, the flow velocity of liquids and gases—these and many other process variables throughout industry may, in time, come under the watchful ear of acoustics.

In the afore-mentioned applications, the sound is used as a measuring stick or flashlight—the amounts of power are small and incidental. In another class of applications, large amounts of acoustic power are employed to do useful work. Vibrational energy is used to drill rock, to machine complicated profiles in one single operation, and to engrave all kinds of jewelry. As a potent microagitator, sound will facilitate the emulsification of liquid mixtures and will speed up such processes as homogenization or dispersion. Sonic cavitation has become a powerful method for the cleaning of precision parts and may find important applications in electrochemistry. Acting on aerosols, such as fumes, dusts, and smokes, sound can speed up agglomeration and collection of particles.

Table 1. Technical fields represented by members of the committee on sonic and ultrasonic engineering of the American Acoustical Society.

Field of commercial activity	Frequency range
Oil-well drilling	20–50 cy/sec
Liquid processing*	0.2–10 kcy/sec
Machining, engraving, and welding	20–30 kcy/sec
Dental drilling	20–30 kcy/sec
Viscosimetry	25–30 kcy/sec
Underwater signaling	2–200 kcy/sec
Cleaning of metal parts	20–700 kcy/sec
Applications in electrochemistry*	20–1000 kcy/sec
Medical therapy	1000 kcy/sec
Nondestructive testing	0.5–15 Mcy/sec
Information storage	10–40 Mcy/sec
Molecular analysis*	Entire range

* Not yet in general industrial use in the United States.

Recently, the Acoustical Society of America organized a technical committee on sonic and ultrasonic engineering. This group had its first meeting during the afore-mentioned International Congress on Acoustics. Its members, comprising economics-conscious industrial engineers and research-minded university physicists, are engaged in the activities listed in Table 1. The frequency range covered by these applications is extremely wide. Their realization therefore entails widely different acoustic engineering practices, which is a characteristic feature—and sometimes a difficulty—of this new field of sonics.

Most of the applications listed in Table 1 have today reached the stage of successful commercial operations; that is, the usefulness to industry of these techniques and instruments has been widely recognized, the development of reliable equipment is more or less completed, and the manufacture, sales, and maintenance of the equipment have proved to be economical.

The three items marked in Table 1 by asterisks—liquid processing, electrochemistry, and molecular analysis—have not yet conquered the market in this country (*1*), although basically they do not appear to be less promising than those which have. In fact, sonic treatment of liquid mixtures and slurries and sonic improvement of electroplating techniques are already in industrial use in Europe. The success of such processing methods depends largely on the availability of transducer mechanisms that are capable of generating sonic power economically, both in sufficient amounts and in a way compatible with the flow of industrial production. If the materials to be treated are encountered in small- or medium-sized batches, conventional transducers of the magnetostrictive or piezoelectric type may handle the job. For example, in the brewery industry such units have been installed for the extraction of vegetable bitters from the hop. They become impractical, however,

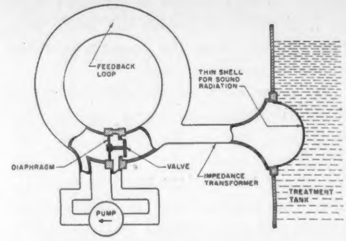

Fig. 1. Hydrodynamic valve oscillator coupled to a treatment tank, according to the method of J. V. Bouyoucos. Direct-current flow energy is provided by a pump. Fluctuations of pressure at the left side of the diaphragm produce a flow modulation owing to changes in the gap area of the valve. The resulting pressure changes at the valve end of the loop are transmitted through the loop back to the diaphragm. Stable oscillations build up at a frequency for which the half-wavelength equals the loop length. Sound energy is extracted from the loop by a transmission-line section terminated by a dome-shaped acoustical window.

for very large batches or high rates of liquid flow. In this case, the recently developed hydrodynamic valve oscillators (*2*) (Fig. 1) or some types of liquid jet transducers may be much more adequate. Both are being considered for large scale dyeing, cleaning, and plating operations.

Molecular analysis by sonic measurement techniques is a particularly fascinating field. So far, however, it has been exploited almost exclusively by university physicists for purely scientific purposes. They have perfected both the theoretical concepts and the required acoustic instrumentation to a high degree (*3*). It would thus appear that the analysis by ultrasonic interferometry of acoustically excited molecules could well become a valuable adjunct to infrared spectroscopy, which utilizes the electromagnetic radiation emitted or absorbed by molecular vibrations.

We may now ask ourselves why the adoption of sonic techniques has been relatively slow in many areas of industry, despite the impressive list of potentially useful effects that have been described in the literature during the last 25 years (*4*). Some relevant answers to this question were given during the afore-mentioned meeting of the committee for sonic and ultrasonic engineering. They may be condensed into the following three key problems, which seem to pose themselves whenever the applicability to industry of a new tool, or process, or instrumentation is being evaluated: (i) the recognition of an existing need; (ii) the demonstration of technical feasibility; and (iii) the economics of both development and operation.

A clear-cut evaluation of these ques-

tions requires a close meeting of minds between the sonics experts, the production engineers, and management—and often a potentially useful approach is abandoned because of the lack of technical liaison. In other cases, the final completion of the development of a process that was shown to be feasible in small-scale laboratory tests did not take place because of excessive costs.

However, sometimes the need, the feasibility, and the economics have been mutually supporting, and a highly successful new instrumentation has emerged. This was the case, for example, in the field of nondestructive testing. Here, the introduction of ultrasonic pulse-echo techniques during the past 10 years (*5*) has filled an urgent need for more sensitive testing methods in a rapidly developing technology (Fig. 2). Moreover, with continued research, the capabilities of the method have been increased beyond the mere detecting of cracks and flaws. It is now possible to evaluate ultrasonically rather subtle material properties such as surface hardness or metal fatigue.

Another example is the use of sonic energy for the cleaning of delicate components of instruments. Conventional methods rely largely on manual manipulation of these parts. As Table 2 shows, the ultrasonic method which does the same job much faster and often more thoroughly, appears to be quite superior from an economic point of view.

But even if the afore-mentioned three basic requirements are met, and a hopeful new product is born, a good deal of continued nursing, mainly in the form of technical education, is necessary to keep it alive and to adapt it to the ever-changing needs of industry. And this again can be achieved only by the cultivation of the relationships between the scientific-minded people in the laboratory and the practical-minded people in the field.

At present the liason between the two groups is far from satisfactory from the point of view of a healthy development of sonic technology. It appears that there are two main reasons: one is the general shortage of trained manpower in applied physics; the other is the need for more interdepartmental training programs at our universities and colleges. Vigorous educational programs already exist in nuclear engineering, they are being considered in molecular engineering (*6*), and they should be initiated in sonics.

Table 2. Analysis of monthly cleaning and repair costs (*10*). The numbers in parentheses in column 1 indicate the quantity.

Assembly	Old method	Ultrasonic
2 CM75 field coil (8)	$1016	$ 408.20
2 CH75 armature (4)	480	198.98
30 E02 field coil (8)	995	451.20
30 E02 armature (8)	928	512.20
1193 field coil (8)	920	336.20
1193 armature (4)	440	236.10
901 field coil (5)	400	128.13
Total monthly cost	**$5179**	**$2271.01**

Fig. 2. Ultrasonic inspection system at Lockheed Aviation Corporation. In the foreground are control panels for programmed scanning. Jet-turbine parts are immersed in the large tank shown in background. The movable bridge astride the tank supports ultrasonic transducer heads capable of following complicated contours.

Basic Physics

Let us now review some of the basic physics underlying the field of sonics. Some examples of the instruments that are currently available for sonic analysis and processing will be described as we go along.

A sound wave is characterized by its speed of propagation and its velocity. In solids, the velocity c is

$$c = \sqrt{\frac{E}{\rho}}$$

where E is the elastic modulus and ρ is the density; in liquids, the velocity is

$$c = \sqrt{\frac{1}{\beta\rho}}$$

where β is the adiabatic compressibility; in gases, the velocity is

$$c = \sqrt{\frac{P_0\gamma}{\rho}}$$

where P_0 is the ambient pressure and γ is the ratio of specific heats.

The wavelength then is $\lambda = c/f$, where f is the frequency of sound—for example, in water ($c = 1500$ m/sec) it is about 5 centimeters at 30 kilocycles per second and about 1.5 millimeters at 1 megacycle per second. In steel, the respective wavelengths are about 4 times as large. The particles in a medium exposed to sound oscillate around their equilibrium positions with a maximum displacement (amplitude) A, a maximum velocity $U = \omega A$ (where the angular frequency $\omega = 2\pi f$), and a maximum pressure $P = \rho c U$. The ratio $P/U = \rho c$ is called the characteristic impedance of the medium, and the product

$$\frac{P \times U}{2} = \frac{\rho c \omega^2 A^2}{2}$$

is the sound intensity. This important quantity is expressed in watts per square centimeter; it may be as low as 10^{-8} watts per square centimeter in analytic sonics and as high as 10^3 watts per square centimeter in sonic processing.

Sound waves may be generated by moving diaphragms or pistons, by devices that interrupt a fluid flow (sirens, jets, valve oscillators), or by slabs of materials that contract or expand under the influence of magnetic or electric fields. Usually the use of each type of transducer is limited to a certain frequency range. It is therefore an important task of the sonic engineer to determine, first, the optimum frequency range from the point of view of the end-result to be achieved and, second, to pick the type of transducer that is most efficient in this range.

Another important quantity is the sound absorption of the medium. It determines the range of penetration of the wave and depends greatly on the homogeneity and structure of the medium.

After this brief survey of acoustic terminology, we are ready to proceed with a discussion of the basic principles involved in (i) the use of sound waves in testing and analysis, and (ii) the processing of materials by sonic energy.

Table 3. Types of waves in isotropic solids.

Item	Pure longitudinal (bulk waves)	Pure transverse (shear waves)	Extensional (rod waves)	Flexural (bending waves)	Surface (Rayleigh waves)
Boundary requirements	Infinite	Infinite	Finite	Finite	Infinite
Dimensions of sample	$d \gg \lambda$	$d \gg \lambda$	$d \leq \lambda$	$d < \lambda$	$d \gg \lambda$
Modulus of elasticity	$\lambda' + 2\mu$	μ	Y	Dependent on λ and d	Dependent on μ and σ
Sound velocity	$\sqrt{(\lambda' + 2\mu)/\rho}$ $\sqrt{\frac{Y}{\rho}\,\frac{1-\sigma}{(1+\sigma)(1-2\sigma)}}$	$\sqrt{\mu/\rho}$ $\sqrt{\frac{Y}{\rho}\,\frac{1}{2(1+\sigma)}}$	$\sqrt{Y/\rho}$ $\sqrt{\frac{\mu}{\rho}\,\frac{3\lambda' + 2\mu}{\lambda' + \mu}}$	Rod of radius r: $\sqrt{\omega r/2} \times \sqrt[4]{Y/\rho}$ Plate of thickness d: $\sqrt{\omega d/2} \times \sqrt[4]{\frac{Y}{\rho}\,\frac{1}{3(1-\sigma^2)}}$	$\frac{0.87 + 1.12\sigma}{1+\sigma}\sqrt{\mu/\rho}$
Wave-type conversion at boundary	Partly to shear wave	Partly to bulk wave	To Rayleigh wave as $\lambda \ll d$	To Rayleigh wave as $\lambda \ll d$	

The two quantities that are fundamental to all measurements are the sound velocity c and the sound attenuation coefficient α, and the solutions of the wave equation are of the form

$$y_x = y_0 \exp.\, j(\omega t - k^* x)\,;\; k^* = \frac{\omega}{c} - j\alpha$$

where y may represent any of the field variables, such as particle displacement, particle velocity, or pressure, and k^* is the complex propagation constant.

The response of matter to elastic strains, such as those occurring periodically in a sound wave, is intimately related to the interactions between the building blocks of matter, the atoms, molecules, or ions. In the case of solids, stiffness may be related directly to the lattice forces, as is suggested by the Grueneisen rule (7). In liquids, the compressibility is proportional to the molecular packing factor s = (molecular volume)/(molar volume): c_{liq} = const. × s, where const. ≈ 5000. In gases the decisive factor in sound propagation is the ratio of specific heats

$$\gamma = \frac{c_p}{c_v} = \frac{f+2}{f}$$

where f is the number of degrees of freedom of the gas. The sound wave propagates by transmitting momentum from molecule to molecule through collisions. In this process, internal molecular vibrations are excited to a degree that depends on the number of effective collisions within each cycle of the sound wave. As a result, the quantity f and with it the effective magnitude of γ may vary with the sound frequency. The time constants involved in the energy transfer by collision depend largely on the presence of impurities in a gas. This suggests the use of sound velocity measurements for gas analysis (Fig. 3), as for example by ultrasonic interferometry.

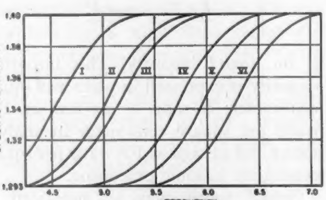

Fig. 3. Influence of impurities on sound velocity in carbon dioxide, according to A. Eucken and R. Becker. I, pure CO_2; II, CO_2 and 5 percent He; III, CO_2 and 11.3 percent CH_4; IV, CO_2 and 5.7 percent H_2; V, CO_2 and 12.3 percent H_2; VI, CO_2 and 2.8 percent H_2O.

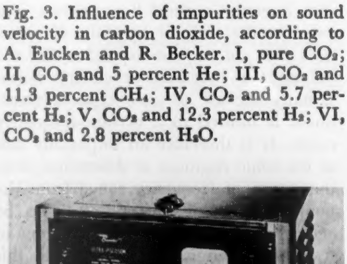

Fig. 4. Ultrasonic viscosimeter. The transducer consists of a longitudinally vibrating magnetostrictive reed. [Courtesy Bendix Aviation Corporation]

Time-dependent adjustments of internal molecular excitation (in gases) or of external molecular configuration (in liquids) to applied compressions are referred to as relaxation processes. Configurational relaxation takes place in certain organic solutions, in electrolytes, and in suspensions of high polymer, long-chain molecules. At those frequencies where relaxation occurs, characteristic changes of sound velocity and sound absorption may be observed. Also, the rheological properties of viscous liquids and slurries may be analyzed acoustically by means of shear waves and by using the characteristic reaction of a medium on a sound source. Measurement of the impedance offered by a "loaded" shear transducer to its associated electric network will thus allow a determination of the complex shear rigidity of the loading medium. Instruments based on such shear-wave impedometry are now commercially available (Fig. 4). Their applications range from the control of petroleum fractionation to the evaluation of blood clotting times.

Techniques

We shall now consider some of the techniques that are used in sonic analysis. For the measurement of sound velocity or wavelength there are two methods of

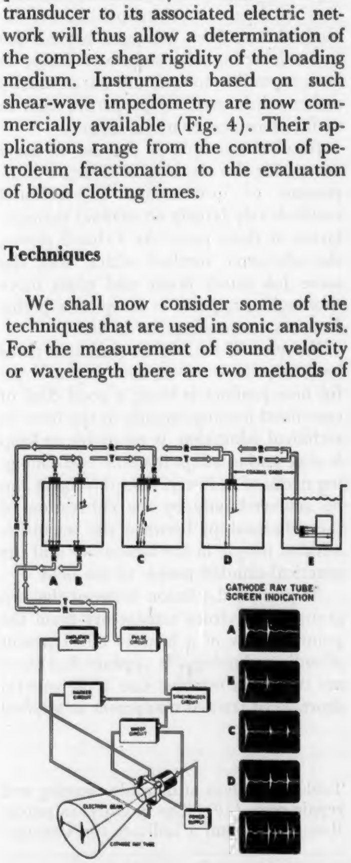

Fig. 5. Ultrasonic pulse techniques. (*A*, *B*) pulse transmission from transmitter crystal T to receiver crystal R; (*C*) pulse reflection method with separate crystals T and R; the extra pip on the oscilloscope indicates a flaw; (*D*) pulse reflection method with a single crystal for T and R; (*E*) immersion technique; the oscilloscope pattern shows multiple reflections between sample boundaries. [Courtesy Sperry Products, Inc.]

choice, standing-wave techniques and pulse techniques. In standing-wave techniques, the periodicity in space of one of the acoustic field variables—pressure, density, or particle velocity—is determined. Typical devices that are widely used are the acoustic interferometer and the impedance tube (8). In pulse techniques, the time required by a short wave train to travel a given distance is measured. Standing-wave techniques are usually more suitable in the kilocycle range of frequencies, whereas pulse techniques are indicated for the megacycle range. The various ways in which ultrasonic pulses may be used to detect flaws in solids or to measure thicknesses or distances are illustrated in Fig. 5. Similar techniques are used for gaging the level of liquids in closed tanks, and pulses reverberating many times in a suitably shaped solid block serve as information storage devices.

At this point we must note that, whereas only one type of wave—namely, longitudinal—exists in gases, additional forms of wave propagation are possible as the rigidity and structure of matter change. We have already mentioned that liquids of high viscosity may support shear waves in addition to longitudinal waves. In isotropic solids we must distinguish between five different types of waves (Table 3). Finally, anisotropy will lead to a dependence of sound velocity on the direction of propagation, with regard to the crystal axes.

If the variation of pressure and the density in a sound wave are in phase, the wave propagates without loss of energy. However, once the period of the sound vibration is comparable with the time constant of one of the afore-mentioned relaxation processes, the density will lag behind the pressure. The loop area of the resulting pressure-density diagram then represents the energy that is lost per cycle. Another cause of losses is multiple reflection or scattering that is caused, for example, by grain boundaries in polycrystalline materials. In principle, such losses may be determined in four different ways, as is illustrated in Fig. 6. They are (i) the time decay of forced vibrations in a standing-wave system, (ii) the decrease in amplitude with distance in progressive waves, (iii) the bandwidth of a harmonic mode of a resonating system, and (iv) the standing-wave ratio in an impedance tube. Many technical materials have been analyzed by these methods, and useful correlations have been established between their loss behavior and other physical properties.

We now come to the other application of sonics—namely, the processing of materials. It has been found that intense vibrations affect colloidal distributions, equalize electrolytic concentrations, and speed up aging processes. Also, by absorption in a lossy medium, intense vibrations may produce local heating effects as, for example, in the use of ultrasonics in medical therapy. In general, one may distinguish between two types of action, effects that are localized at interfaces between different kinds of media or between constituents of the same medium, and volume effects. Interface effects play a predominant role in power sonics and lead to a number of unusual phenomena. They are produced more readily than volume effects. For example, small bubbles or particles suspended in a liquid are subjected to drag forces in a sound field; similar forces come into play if a sound field interacts with an aerosol. This, then, is the physical basis for such processes as sonic stirring, degassing, and coagulation.

A particularly powerful phenomenon is cavitation. This is the breakdown of the cohesion of a liquid that is exposed to high tensile forces as the sound wave passes through it. Such breakdown usually occurs at the weakest points within the liquid. Tiny bubbles, dust particles, and particularly interfaces where poor wetting conditions exist, facilitate the onset of cavitation. As the term cavitation implies, cavities are formed in a liquid during the negative pressure phase of the sound wave; these subsequently collapse during the positive pressure phase. Such cavity collapses may produce pressure peaks of several hundreds of atmospheres. Under the influence of cavitation, steel surfaces may be pitted, oxide layers removed, bacteria disintegrated, or high polymers depolymerized. One particularly successful application of surface cavitation is in ultrasonic drilling; another is in the soldering of aluminum.

The periodic strains set up by intense vibrations in metals or solidifying melts (9) are capable of rearranging dislocations or impurities in some materials. This may have an effect on crystallization, grain formation, and precipitation hardening. A promising electrodynamic method for exciting whole crucibles to intense radial vibrations at frequencies of 10 to 50 kilocycles per second is shown in Fig. 7.

The number of specific examples that could be given in this review of the present scope of sonics is of necessity limited. However, it may give the reader some feeling for the potential usefulness of acoustic instrumentation in certain industrial tasks. It is safe to say that acoustical physicists who are interested in the growth of sonics are eager to accept the challenge of their industrial colleagues to put sound waves to work. Progress during recent years has been encouraging, and with improved contacts among in-

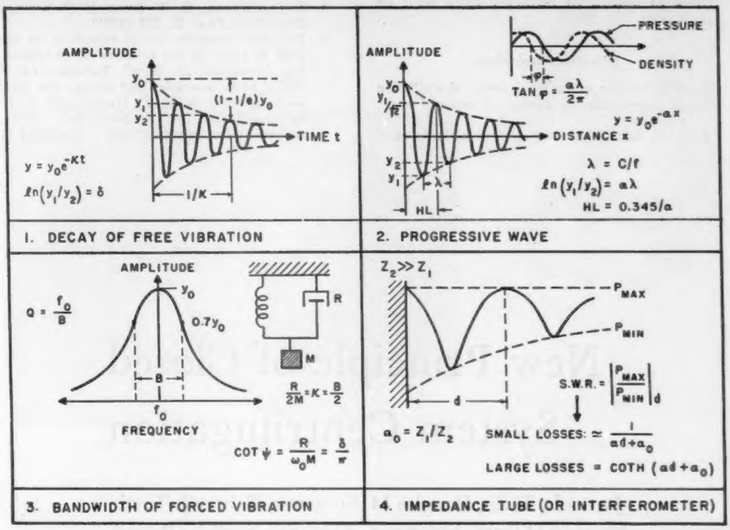

Fig. 6. Basic techniques for attenuation measurements: κ, temporal damping constant; α, spatial attenuation constant; δ, logarithmic decrement; Q, quality factor, S.W.R. = standing-wave ratio.

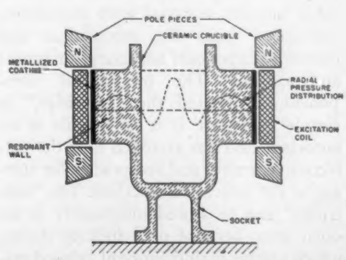

Fig. 7. Vibrating crucible for irradiation of metal melts, according to H. Seemann.

terested parties more valuable contributions of sonics to industry may well be expected.

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New Principle of Closed System Centrifugation

James L. Tullis, Douglas M. Surgenor, Robert J. Tinch, Maurice D'Hont, Frederic L. Gilchrist, Shirley Driscoll, William H. Batchelor

Owing to its easy availability, blood was one of the first human tissues to undergo definitive chemical study. However, certain of the components have been difficult to obtain in their true state in nature. This often has given rise to conflicting data. The dynamic state of blood within the body, as well as its peculiar property of being able to change from a liquid to a solid, makes the static conditions of blood outside the circulation highly artificial. The early discovery that citrate and other calcium complexing agents would block coagulation has been estimated (*1*) to have slowed certain types of hematologic research by several decades. This is not due to intrinsic damage from citrate ion. Rather, it is because blood rendered incoagulable can be collected without attention to its labile components. This has led to the universal collection of blood, for either analysis or therapy, under nonphysiologic conditions; rubber tubing, warm glass bottles, and anticoagulant solution, followed by a variable storage period during which the equilibrium state of cell destruction and resynthesis no longer obtained.

In an effort to surmount these conditions, work was begun in 1949 by Edwin J. Cohn and collaborators on equipment designed to collect and fractionate blood as early as possible in its natural state. The underlying principles were simple: rapid cooling, nonwettable surfaces, low turbulence, minimal gravitational forces, closed-system sterility, and rapid removal of the cytologic components before enzymatic degradation could ensue. In an effort to make these fundamental techniques applicable to tissues other than blood, the engineering was developed in such a manner that broad versatility was permitted. As a result, a basic centrifuge system was evolved which has almost equal application to virus purification, milk stabilization, and the separation of other multiphase systems. Its performance thus far has been chiefly assayed in the blood field, owing to the central theme of the originating laboratory (*2*).

Closed System

In the design of the apparatus, all parts that come into contact with blood or other biologic material were completely segregated from the mechanical and electric components necessary for power and control. The mechanical component, designated the "cartridge," is simple in design; it is sterilizable in an autoclave and has attached to it the collection assembly and receptacles for storage of the individual fractions. The "cartridge" can be stored indefinitely in an open area, because of a locking device which assures maintenance of "closed system" sterility (Fig. 1).

Collection of the effluent fluids and cell suspensions is accomplished by means of coaxial rings which are a part of a dynamic or centrifugal valve. Thus, effluent discharged under centrifugal force is collected in an outer annular space; the material that drains after decelerating the bowl is collected in a separate, inner, annular chamber. Adoption of this principle avoids the need for manifolds to control the flow of liquids into their respective receivers. All connections into and out of the apparatus are thus made on a stationary, collecting assembly (Fig. 2).

Three basic bowl designs are employed in the centrifuge: an inverted conical-shaped, two-compartment bowl (type I); a peripheral-feed, long-traverse bowl (type II); and an inverted, cylindrical, falling-film bowl (type III). These make possible diverse types of separation which involve the removal of cells or precipitates from a liquid medium. The three bowls also possess internal flexibility by means of a locking device in the midportion of the bowl. This permits the insertion of various dividing baffles without change in the outside dimensions or in the relationship of the bowl to the drive mechanism. It also permits facility of disassembly for thorough washing, resurfacing, and removal of pyrogens.

Type-I Bowl

The separation of certain cytologic components of the blood is a typical example of the use of type-I bowl (Fig. 3). Blood contains three formed elements of varying average densities—red cells (1.095), white cells (1.065), and platelets (1.032)—suspended in liquid plasma. Sedimentation (either spontaneous or accelerated by rouleaux reagents) and low-speed centrifugation have generally been used for separation of the three kinds of cells. The densities of the three cell types represent average values only. Considerable variation exists in both size and weight. As a result, no single mechanical system has ever led to a pure yield of cells. Partial purification of a single kind of cells has been achieved by repeated packing of blood in a bucket-type centrifuge with pipette removal of the layer that most closely corresponds to the desired cell population. The present device permits a continuous-flow system

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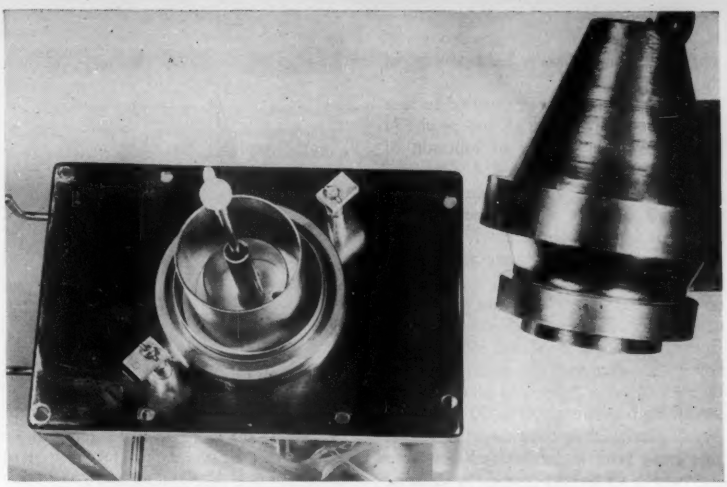

Fig. 2. Collecting cup and assembly with centrifuge bowl removed.

wherein such recycling can be effected in a closed system without alteration of the overlying gas phase and without penetration of a sterile seal.

Continuous separation also permits the use of a small centrifuge vessel, since only a part of the total volume is in the bowl at any given time. The shape of the separation vessel is critical and should vary with the centrifugal force employed, the specific gravity of the various cells, and the average viscosity of the liquid phase, in this instance, plasma. For the separation of red cells at a low centrifugal force, the ideal shape is that shown in Fig. 3. Incoming blood enters from below and feeds by gravity to the top of the inverted cone at a flow rate of 50 milliliters per minute. This is controlled by the height of the donor or blood bottle above the apparatus. It impinges onto the revolving surface at nearly dead-center so that minimum shearing force occurs. Thence, it flows to the periphery of the bowl and then by gravitational force passes down through the centrifugal field.

The forces acting on blood cells in the upper compartment of a bowl revolving about a vertical axis are centrifugal force, moving the cells outward, and gravitational force, moving the cells downward. In a centrifuge operating at less than 450*g*, this second factor assumes considerable importance. The shape of the upper compartment of type-I bowl is so designed that it permits maximal cell accumulation with minimal convexity along the inner face of the red cell mass as it advances toward the central (overflow) axis. As the upper bowl fills, plasma is displaced and overflows along a central weir which embodies an automatic valving principle.

After 500 milliliters of blood has passed through the apparatus, 220 milliliters of clear plasma will have passed into an individual container leaving the red cell mass, the overlying layer of "buffy coat," and enough retained plasma to permit fluidity. If a high plasma yield is desired, the centrifugal force is increased to 475*g*, thus packing the cells tighter and yielding an added increment of 25–35 milliliters of clear plasma on partial deceleration.

The dynamic state within type-I bowl revolving at 425*g* is postulated as follows: at a fixed flow rate, temperature, and rotational speed, the only variable is that of red cell volume. The inflow blood enters the apex of the inverted bowl and flows outward at a fixed rate of acceleration. Red cells begin to accumulate at the edges of the bowl. The density of material within the bowl ranges from 1.027 (plasma) to 1.095 (red cells). At a given point along a vertical axis within the bowl, a *static zone* will exist whose density is higher than that of white cells and lower than that of red cells. This zone remains static because red cells and plasma leave, owing to centrifugal force, as fast as red cells in miscible plasma enter, owing to constant flow rate. The white cells never penetrate this zone, because of its density. Likewise, they never pack, owing to continual bombardment of entering red cells and escaping plasma. The accumulation of red cells disturbs this static zone as it moves toward the point of overflow.

A buffy coat layer begins to form after the bowl capacity has been reached, because the effective centrifugal force has decreased owing to red cell accumulation, thus producing less disturbance at the zone of interface. If the buffy coat is desired as a separate component, the revolving bowl is decelerated slowly to 40*g*, but is not stopped. The resulting decrease in volume causes spillage of approximately 25 milliliters of cell concentrate with a mixed population of red and white cells in an average proportion of 5 red cells to 1 white cell. The white cell yield of this mixture may later be increased, either by recycling the buffy layer or by recycling plasma as a "wash" over the inner surface of the revolving red cell mass.

White cell recovery. In attempts to improve the recovery of the "buffy coat," many variations in bowl principle and operating technique have been studied. These include peripheral feed, rather than central feed, and variation in flow rate and centrifugal force. One method consists of blood collection into a bowl in which the standard central part is replaced by a single baffle dividing the bowl into upper and lower compartments. At the end of a 500-milliliter phlebotomy, the red cell bowl is decelerated to 60*g*, and saline is introduced through the feed port at a rate of 250 milliliters per minute. This effectively removes part of the buffy coat layer and yields as high as 70 percent of the theoretically available

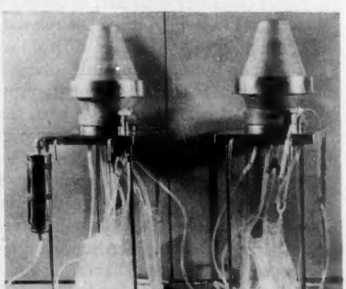

Fig. 1. Two assembled cartridges ready for insertion into centrifuge.

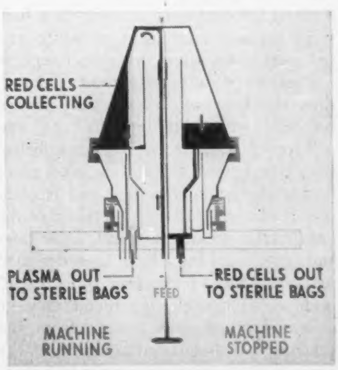

Fig. 3. A stainless steel, two-compartment bowl with continuous flow to the top of inverted cone. Capacity of upper compartment, 280 milliliters at 425*g*. Lower weir contains dynamic valve for separation of overflow liquid from precipitate, which remains in bowl during operation and drains through separate port after deceleration.

white cells, mixed with 7–10 percent of the red cells.

The suspension can be purified further by passing it through a second bowl (*3*) containing a thin layer of albumin of density 1.078. The recovery of leucocytes from this second purification averages 20 percent of the theoretic number of cells entering the second bowl. The ratio of white cells to red cells averages 1/4.

Another method requires interruption of the initial red cell-plasma separation after 8 minutes of centrifugation. Blood from the donor is collected into a reservoir rather than into the revolving bowl. Four hundred milliliters of blood is then forced from the reservoir at 50 milliliters per minute and is centrifuged at 425*g*. The bowl is then decelerated slowly to 60*g* over a 45-second period. A yield of 50 milliliters of plasma is obtained by this deceleration. An average of 17 percent of the white cells is present in this plasma with a white cell-to-red cell ratio ranging from 1/1 to 1/3. The bowl is then reaccelerated to 425*g*, and the remaining 100 milliliters of blood is introduced from the reservoir in a 2-minute period. Deceleration is again accomplished as in stage one with a recovery of an added white cell increment which averages 25 percent.

Mixed platelet and buffy coat recovery. Under routine methods of collection, the concentration of platelets in the buffy coat is generally small, averaging less than 20 percent. This is due to the low density of platelets and the high viscosity of plasma at operating temperatures of +4° to +10°C. If it is desired deliberately to include platelets in the buffy coat, the original separation can be effected at higher gravitational force or the inflow of blood can be halted after full-bowl capacity is reached, and the entire mass can be centrifuged in a static state. The method for obtaining platelets in a high yield without admixture of white and red cells is described in another section.

Packed red cells and plasma. The routine, semiautomatic recovery of packed red cells (with overlying buffy coat) and cell-free plasma is easily accomplished with type-I bowl. Separation takes place during the actual bleeding and is completed synchronously with removal of the needle from the donor's arm. Flow rates and centrifugal force have been designed to correspond to bleeding times of 10 minutes. If desired, the blood may be collected in an area remote from the centrifuge with later attachment of the machine and subsequent sterile fractionation. A separate individual "cartridge" consisting of the revolving bowl, attached containers, in-flow tube, cooling coil, and anticoagulant solution or ion-exchange resin column, is used for each individual phlebotomy. In a consecutive series of 1575 red cell-plasma separations, clear plasma was obtained on 1480 occasions. In 30 collections, slightly pink plasma was obtained, owing to friction at the top of the feed tube from excessive spring pressure. A small overflow of red cells occurred during the last 50 milliliters of plasma in 65 other collections. This was generally due to an abnormally high red cell mass in the donor blood.

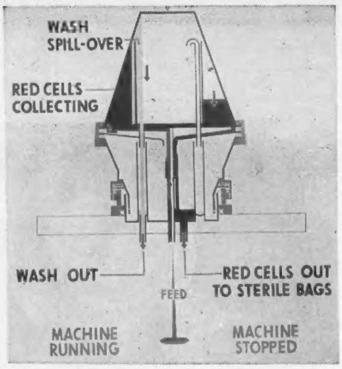

Fig. 4. Stainless steel, two-compartment bowl with continuous feed to the undersurface of central plate. Capacity of upper compartment approximately 350 milliliters at 425*g*. During operation, the upper compartment drains by overflow along a central tube that traverses the lower compartment without entering it. Cells from the upper bowl drain backward into a separate container following cessation of centrifugal force.

Four hundred eighty of the 1575 collections were made with the blood first passing into a reservoir containing anticoagulant solution with subsequent transfer into the revolving bowl. Anticoagulation in the other experiments was by calcium removal on a sodium cycle, cation-exchange resin. The average plasma yield was 220 milliliters.

In order to check accurately on the viability of red cells separated in the centrifuge, a collaborative study was made in association with John G. Gibson II, at the Harvard Medical School. The postinfusion survival of red cells that had been separated and processed in the centrifuge was studied in ten experiments by the radiochromium technique. The *in vivo* survival characteristics were compared with the well-documented survival of red cells collected into ACD anticoagulant solution NIH Formula B and manually separated. The results are fully reported elsewhere (*4*). It was concluded from the study that red cells separated in this apparatus, showed *in vivo* survival which compared favorably with cells that had been collected and separated by standard techniques.

Type-I bowl recently has been used elsewhere for experiments in plasmapheresis and leucopheresis. The completely closed system makes possible the reinfusion of a selected component of blood back into the original donor without fear of bacterial contamination. Early plasmapheresis experiments in an "open system" by Griffols-Lucas (*5*) suggested this as a means of increasing the yield of a given component of blood. Later calculations by Stokes (*6*) emphasized the public-health implications of such controlled bleedings. It was postulated that the (biweekly) bleeding of 2900, high-titer, hyperimmune donors with reinfusion of their red cell mass at the time of each bleeding would result in the same yield of antibody-containing gamma globulin as the present random annual bleeding of 4 million normal donors. Experiments on the adaptability of type-I bowl to plasmapheresis is under study by Stokes and Smolens and is the subject of a separate report (*7*). To date, 550 plasmapheresis experiments have been carried out in this manner without reaction.

Studies by Stephen Chapman at the University of Louisville have shown a unique effectiveness of the standard red cell-plasma bowl for concentration of virus by adsorption on red cells and by precipitation through the addition of zinc reagent inside the revolving bowl. The continuous-flow (recycling) capability of the system makes possible the isolation of small amounts of virus from large quantities of material. The closed system simultaneously assures protection of the experimenter and of the virus itself (*8*).

Type-II Bowl

The infusion of glycerol into red cells and the removal of glycerol from frozen and thawed red cells are typical examples of the use of type-II bowl (Fig. 4). It has recently been demonstrated (*9, 10*) that treatment of red cells with glycerol or other polyhydric alcohols will permit subsequent long-term storage at a temperature below freezing. Such cells possess *in vivo* and *in vitro* survival which compares favorably with that of ordinary "banked" blood which has a 3-week dating period at +4°C. The single factor that has most significantly delayed the application of this revolutionary principle to blood preservation has been the advisability of removing the glycerol prior to reinfusion into a recipient. The rate of water endosmosis is roughly 4 times greater than glycerol exosmosis. Red cells containing a high concentration of glycerol, when placed in an aqueous phase containing 0.15*M* sodium chloride and no glycerol solution, will take in water so much more rapidly than they will give up glycerol that prompt swelling and lysis occur. The standard laboratory methods of equilibrating with

glycerol before freezing and removing glycerol after freezing and thawing are time-consuming and difficult to accomplish with sterile technique.

Glycerolization and deglycerolization. Blood collections of 500 milliliters each are made into a reservoir containing anticoagulant solution. The blood is then forced to the undersurface of the metal plate in the mid-portion of the bowl at a flow rate of 45 milliliters per minute, with a gravitational force of 425*g* within the revolving bowl. The suspension passes to the periphery and enters the upper chamber by centrifugal force. As the upper bowl fills to its capacity of 350 milliliters, the blood separates into a lighter plasma layer and a heavier red cell layer. The clear plasma rises to the inner axis and overflows through an exit tube. The overflow plasma is collected separately and may be used for platelet concentration or any other desired purpose. Without interruption, a glycerol solution (Table 1) is introduced at a flow rate of 30 milliliters per minute until a total of 1000 milliliters has been passed through the bowl. When desired, a series of solutions of increasing glycerol content may be used. This permits a more rapid flow rate (owing to lower viscosity) and avoids the slight hemolysis that sometimes follows the direct introduction of 40-percent glycerol. The bowl is then stopped, and the glycerolized red cells drain into a suitable container for removal and storage at the desired temperature below freezing.

To remove glycerol from previously frozen and thawed cells, the process is essentially reversed. The thawed cells are fed into an empty revolving bowl. Glycerol rises to the inner axis and overflows. Two wash solutions (Table 1) are attached to the assembly in a tandem arrangement and are forced into the bowl in such a manner as to give a gradual gradient between the two solutions so that the first wash contains 10-percent glycerol and 0.496*M* lactate, whereas the final wash contains 0-percent glycerol and 0.156*M* lactate. These solutions have less density than the heavy glycerolized cells and rise toward the inner axis, maintaining a slow but constant flow, thus dialyzing all glycerol from within the red cells. A total wash volume of 4 liters is used. Finally, a suspending medium is introduced to displace the final wash solution. The centrifuge is stopped and the red cells are allowed to drain by gravity into a bottle or bag containing protein, glucose, and isotonic salt.

The recovery of red cells at the completion of the full processing of glycerolization, freezing, thawing, and deglycerolization varies from 70 to 90 percent. The final glycerol concentration averages less than 200 milligrams, as assayed by the method of Karnovsky (*11*). Cells so treated have shown osmotic fragility curves equal to freshly isolated cells that have not undergone glycerolization and freezing. Successful *in vivo* survival studies utilizing chromium-tagged cells processed in this manner are the subject of a separate report (*12*).

Approximately 150 units have been glycerolized and 200 units deglycerolized by these techniques. The average elapsed time for glycerolization has been 45 minutes and for deglycerolization 120 minutes. The process is semiautomatic, and, once proper flow conditions are established, multiple separations can be instituted, thus greatly shortening the operation time per unit of cells. The amount of hemolysis and free hemoglobin in the supernate is related to the time of storage, temperature of storage, and glycerol content rather than the processing itself. For direct processing and freezing without prolonged storage, the cell loss from hemolysis averages less than 1 percent (*13*).

Table 1. Ingredients for solutions

Glycerolizing Solution	
Sodium lactate	0.156*M*
Glycerol	40% (w/v)
Potassium Chloride	0.004*M*
Distilled water	q.s.
Deglycerolizing solutions	
Wash solution No. 1:	
Sodium lactate	0.496*M*
Glycerol	10% (w/v)
Potassium Chloride	0.004*M*
Distilled water	q.s.
Wash solution No. 2:	
Sodium lactate	0.156*M*
Potassium Chloride	0.04*M*
Distilled water	q.s.

Type-III Bowl

The separation of platelets from fresh plasma is a typical example of the use of the type-III bowl (Fig. 5). Platelets have an average density of 1.032. Their removal from plasma, which possesses only a slight difference in density, is further complicated by the increased viscosity of plasma at low temperatures (0° to +4°C) that are optimal for platelet preservation.

Classic methods for platelet concentration require prolonged centrifugation at high speeds in order that the platelets may traverse the depth of plasma present in an ordinary blood bottle or plastic bag. This lengthens the time that the cells are in contact with their substrate coagulation proteins under *in vitro* conditions. Moreover, the standard techniques do not permit continuous-flow, closed-system methods which are necessary in order to wash completely the

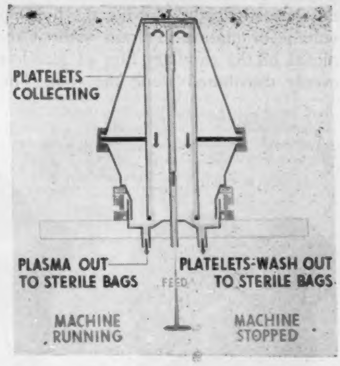

Figure 5. Stainless steel, single-compartment cyclindrical bowl, with continuous flow to top plate. Capacity 25 milliliters at 250*g*. Drainage through single outlet port in collecting cup.

platelets free of plasma proteins. Experience with the new falling-film type of bowl points to markedly increased platelet yields with fewer altered properties.

Platelet concentration for in vitro and in vivo use. Five hundred milliliters of fresh whole blood is collected over an appropriate deionizing column of carboxylate resin on the sodium cycle or into an attached reservoir containing anticoagulant solution. The blood then flows into type-I bowl, which is modified by the inclusion of a ¼-inch spacing ring to increase the volume to 324 milliliters. Operating conditions for this separation include reduction of centrifugal force to 300*g* or less with maintenance of the standard flow rate of 50 milliliters per minute. This permits retention of a higher platelet content in the overflow plasma: averaging slightly greater than 60 percent in 50 experiments.

If it is desired to recover the platelets that remained with the red cell mass, the packed red cells may later be resuspended in the platelet-free plasma and recycled through type-I bowl (*14*). The overflow plasma containing platelets is then passed at a flow rate of 10 milliliters per minute under positive nitrogen pressure through a connnecting tubing into type-III bowl and centrifuged at 250*g*. After the first 25 milliliters of plasma has entered, all subsequent plasma passes as a film over the surface and emerges through the single collecting port at the bottom. This reduces to a few millimeters the distance any platelets or precipitate must move to be freed of the liquid phase as it falls in a film through the centrifugal field.

During the exposure to the centrifugal field (approximately 8 seconds) the cells move out of the axial flow and eventually concentrate in a capillary layer along the sides of the bowl. At the com-

pletion of the separation, the bowl is decelerated slowly allowing the hold-up volume of plasma to drain without removal of the capillary film of platelets evenly distributed along the wall. The bowl is then reaccelerated and a series of wash solutions is introduced through the original feed port. The process of washing and draining can be repeated until the desired freedom from entrained protein is achieved. The bowl is then decelerated abruptly. This has the effect of scooping the platelets from the wall of the container, causing them to flow out in an even suspension.

In 150 consecutive experiments, the platelet counts in the final storage media have averaged 800,000 per cubic millimeter, representing an average yield of about 50 percent of the available numbers (*15*). Platelets isolated by this technique have been the subject of extensive *in vitro* and *in vivo* study. They have shown stability sufficient for preservation in excess of a year by methods outlined elsewhere (*16*).

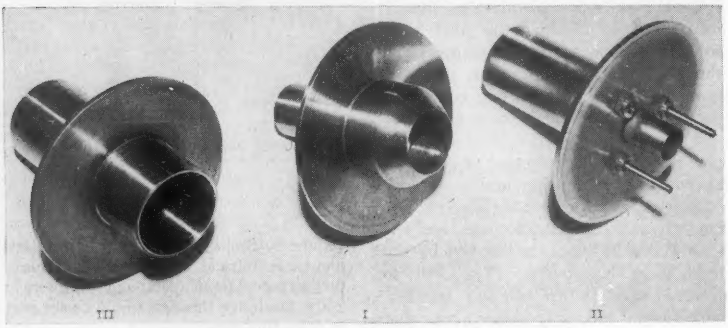

Fig. 6. Angle view bowl inserts 1, 2, and 3.

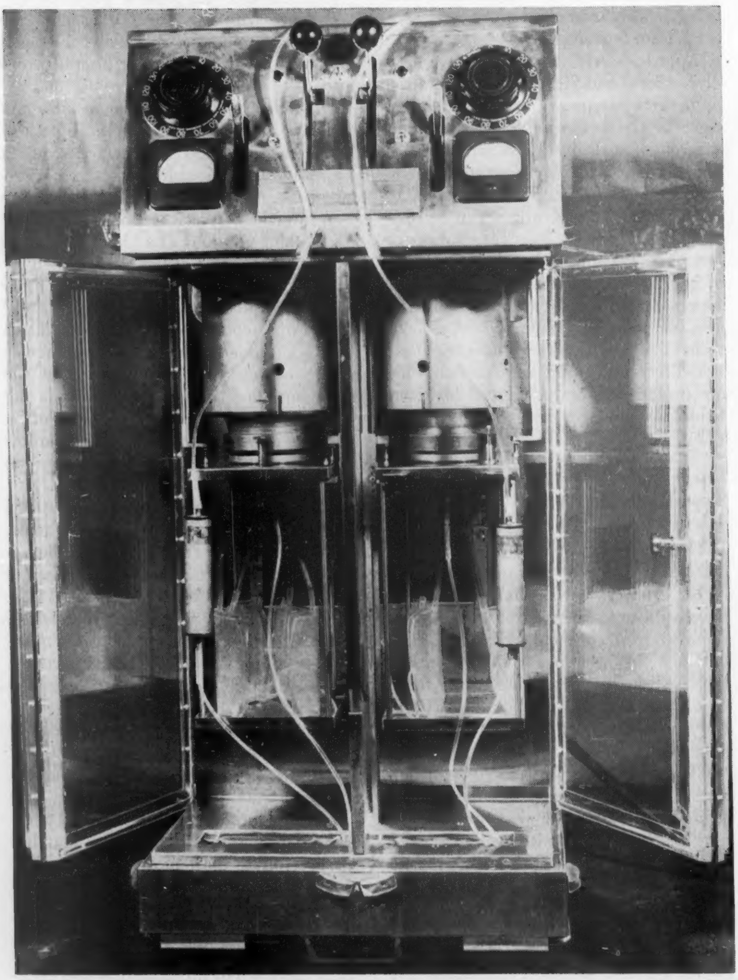
Fig. 7. Close-up centrifuge showing two bowls in operating position. Donor tubes extend from top to ion-exchange columns, cooling baths and thence into centrifuge bowls.

Sterile Seal

The desired bowl, centrifugal valve, stationary feed tube, collecting assembly, and attached plastic bags, tubing, resin column (or anticoagulant), and donor set are all mounted prior to sterilization. A firm locking device holds the various rotating parts in firm apposition with the collection system, so that no precautions are necessary for prolonged storage in an open room. Moreover, the autoclave methods include passage of steam and sterile nitrogen gas through the bag or bottle assembly, so that positive pressure is maintained during storage. Inspection of the "cartridge" before use for presence of inflated bags assures effectiveness of the seal. Any leak, if it were to occur, would be in an outward, rather than an inward, direction, owing to the internal positive pressure during storage.

At the time of use, the locking device is removed. Contact is maintained between the bottom of the revolving centrifuge bowl and the uppermost part of the stationary collecting system by gentle spring pressure on a graphite ring which mates with a stainless steel ring. The opposing stainless steel and graphite surfaces are ground flat, with the result that minimal contact between the two surfaces will still result in an airtight and bacteriologically sterile barrier. The properties of the graphite are such that high rotational force can be employed without significant frictional heat and without resorting to lubrication.

During operation, the drive force on the centrifugal bowl is applied from the outside. Positive pressure can be maintained in the bowl during operation, and any desired mixture of gases may be employed. The seal effectively protects the centrifuged material from bacterial contamination as well as the operator from the material being centrifuged. This latter condition is of singular importance in the handling of plasma contaminated by icterogenic virus or other toxic materials.

In order to corroborate the effectiveness of the seal, a collaborative program was conducted in association with the

research laboratories of a manufacturer of commercial sterilization equipment. Plastic bags containing red cells and plasma processed through the various afore-described bowls were shipped from Boston to Erie, Pennsylvania, by air express. Shipments were made twice weekly during an 8-month period and comprised 81 samples: 39 bags of red cells, 41 bags of plasma, and one bag of whole blood reconstituted after processing. Upon arrival in the collaborating laboratory, all samples were cultured and studied, utilizing techniques that followed closely those outlined in the 14th revision of *U.S. Pharmacopoeia.*

The results of this study, comprising 1040 cultures on 39 samples of red cells, 41 samples of plasma, and one sample of whole blood, were negative for bacterial growth with the single exception of the cultures from one bag of plasma that had ruptured during aerial shipment. Since completion of this study, the adequacy of the seal has been further corroborated by the routine processing of more than 500 samples of blood products which subsequently have undergone culture or direct *in vivo* use.

Concurrently with the bacteriologic testing, 43 routine samples of red cells, plasma, and platelets were also tested in animals for pyrogenicity. Rabbit testing was carried out at the Commonwealth of Massachusetts, Division of Biologic Laboratories according to *U.S. Pharmacopoeia,* revision 14. The tests showed a uniform absence of pyrogens. The same 500 samples of blood that have corroborated the sterility data also have shown freedom from pyrogens. The satisfactory performance of the equipment in this regard is believed to be due to the simplicity of the bowl assembly. Each of the three bowls can be disassembled into a conical-shaped upper and lower half (similar for all types of assembly) plus any one of the three central bowl inserts (Fig. 6). These latter are varied according to the type of centrifugation desired.

General Equipment

The three bowl principles outlined here and the complete seal unit have been incorporated into a single dual-unit drive mechanism (Fig. 7). This equipment has recently become available commercially (*17*) for research use. It contains complete refrigeration equipment for prompt cooling to +4°C with maintenance at temperatures between 0° and +10°C throughout the period of experimentation. It is mobile and can be operated from standard electric circuits of 25-ampere, 115-volt, 60-cycle single phase. Its dual-drive control permits two completely different experiments or types of centrifugation to be carried on simultaneously. The activation and braking mechanisms permit sensitive control, so that the speed of centrifugation can be varied without turbulence.

Visualization of the separation process is not possible until after the initial overflow of plasma. This occurs at about 7 minutes following institution of a standard red cell-plasma separation. For volume measurement, one can compute the measured overflow content (volumetrically in a bottle, gravimetrically in a bag) and add to the fixed volume of the bowl. For standard operations in which accurate volume measurement is not required, simple timing of flow rate has proved satisfactory. For example, in standard blood separation directly from a donor, the flow is interrupted after 10 minutes on the presumption that approximately 1 pint of blood has been collected.

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Solar Furnace in High-Temperature Research

Tibor S. Laszlo

The large amount of solar energy that reaches the surface of the earth and is freely available to everyone is a great challenge to energy-conscious scientists and technicians. The world-wide interest in this problem was strikingly demonstrated at the first World Symposium on Applied Solar Energy held in Phoenix, Arizona, in November 1955 (*1*).

Solar energy is already used in experimental installations to drive engines, to heat and cool houses, to distill water, to cook food, and to generate electricity. Wherever conventional fuels are in short supply, wherever energy requirements are small and sunshine is abundant, solar energy may find limited application. But in all these uses it remains a substitute in the true meaning of the word. It must compete economically and in convenience with other forms of energy. Accordingly, whenever conventional forms of energy, including nuclear energy, become readily available, the use of solar energy loses its economic or technical justification.

There is, however, one application in which solar energy is superior to any

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other form of energy presently available, namely in the field of high-temperature research.

Conventional High-Temperature Furnaces

Conventional furnaces used in high-temperature research have a number of serious shortcomings. The first of these is the relatively low temperature ceiling that is obtainable. With gas-fired furnaces, the temperature maximum is about 1800°C. Electric resistance furnaces may reach higher temperatures, in special arrangements up to 2800°C, but heavy penalties must be payed in the reduced convenience and flexibility of operation. In such furnaces an inert gas atmosphere has to be maintained, and this has many inherent complications.

The theoretical temperature limit of the induction furnace is the melting point of the magnetic susceptor material in which the high-frequency alternating current generates heat by induction. In practice, however, temperatures seldom exceed 2700°C, since even above 2000°C radiation from the susceptor becomes very intense. Insulators and reflectors have to be used to keep energy losses low and to prevent failure of the copper reduction coil. In many cases, a water cooling jacket is used between the work coil and susceptor. As a consequence, the induction coil and susceptor are placed farther apart; hence, the coupling is poor and the maximum obtainable temperature is lowered.

Another restriction on induction furnaces is that only magnetically susceptible materials may be directly heated in it. If the sample is not a susceptor, an auxiliary susceptor has to be used, and the sample is heated by radiation. It is very difficult to find a satisfactory auxiliary susceptor, because it must have a higher melting point than the desired reaction temperature, and it should not react with the sample, the parts of the furnace, or the atmosphere in the furnace. Carbon is frequently used as an auxiliary susceptor, but the reduction of oxides and the formation of carbides constitute a serious limitation.

Carbon-arc furnaces are used for higher temperatures, but the reduction of oxides and the formation of carbides are even more restrictive here. In addition, the hot zone is very small, uniform temperatures are difficult to obtain, and close temperature control or gradual change of temperature is impossible.

Whether they use gas or electricity, all these furnaces have one disadvantage in common, the need for a container to hold the sample being heated. The container should exhibit good mechanical and chemical stability at the operating temperature, and it should not react with the sample or any other matter in the furnace. In many cases, it is also desirable that the sample should not become an electric conductor or magnetic susceptor even at high temperatures. It is very difficult to meet these requirements. Frequently, before an investigation at high temperature is undertaken, an auxiliary research project has to be carried out to develop a suitable container material. This secondary project may require more time and effort than the investigation of the main problem, and sometimes no satisfactory container material can be found.

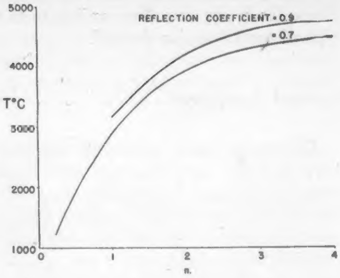

Fig. 1. Correlation of reflector dimensions and maximum obtainable temperature of paraboloidal concentrators of solar radiation; n = diameter/focal length.

Advantages of the Solar Furnace

The use of solar radiation to generate high temperatures offers an elegant solution to these problems (2). The temperature limit is thereby extended beyond the previously mentioned values. With a 60-inch-diameter solar furnace, 3500°C has been reached at Fordham University, and it is possible to build furnaces to reach temperatures of more than 4500°C. Figure 1 shows the correlation of reflector dimensions and maximum obtainable temperature. The upper curve (coefficient of reflection = 0.9) represents values for highly polished silver or aluminum reflectors. Metals of better corrosion resistance, such as stainless steel and stellite, would yield temperatures along the lower curve (0.7). All these values refer to geometrically perfect paraboloidal reflectors.

Just as important as the high temperature is the ideal experimental condition that exists in a solar furnace. Radiation energy is a very pure heat source. No combustion products and no vapors of refractories or resistance elements are present as contaminants. Since the material to be heated acts as its own crucible, reactions between sample and container are eliminated. Also eliminated are reactions between the sample and other parts of the furnace, since the parts of the furnace remain virtually at atmospheric temperature during the entire heating process.

Since it is possible to raise the temperature to 3500°C within a few seconds, the cycle of heating is very short. The cooling period also is very short, since the sample is not surrounded by a large mass of hot refractory material. Thus, effective quenching, so important in phase studies, can be performed conveniently. If, however, slow heating or slow cooling is required, these too are possible, since the temperature can be controlled closely even at the top range. Furthermore, it is possible to perform the heating in air, in any desired atmosphere, and at low or moderate pressure.

Heating the sample under experimental conditions is only one part of high-temperature research. It has to be combined with observation and measurement during heating. These too can be accomplished far better in the solar furnace. Since only part of the sample is heated, and since the entire surroundings remain at atmospheric temperature, the observation and measuring instruments may be placed quite close to the sample. There is no electromagnetic field to interfere with the measurement of electric properties. It is possible to repeat a test within a few seconds by moving, with the aid of a servomechanism, an unreacted portion of the sample into the focal point.

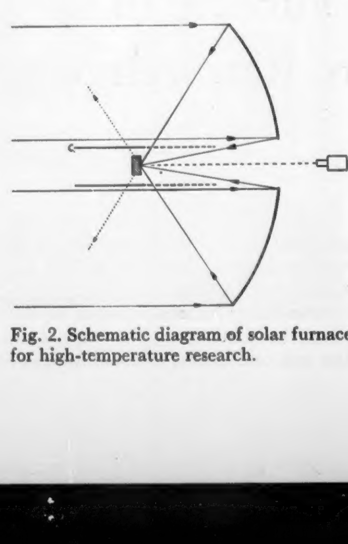

Fig. 2. Schematic diagram of solar furnace for high-temperature research.

Operating Principle

Figure 2 shows the operating principle of the solar furnace. Solar radiation is concentrated by a paraboloidal reflector on the sample placed in the focal zone. Since the reflected radiation forms a double cone (dotted line) with the apex at the focal zone, the size of the heated area may be increased by moving the

sample along the axis of the cones in either direction. As the heated surface increases, the energy density—that is, the temperature—decreases. Another method of decreasing the maximum temperature consists of moving a reflecting cylinder C into the position indicated by the broken line, thus preventing part of the reflected radiation from reaching the sample. By making the movement of both sample and cylinder continuous, good, gapless temperature control may be achieved.

The solar energy reaching the atmosphere of the earth is 2 calories per minute, per square centimeter. Because of atmospheric absorption and dispersion, this value is reduced to approximately 1.6 calories per minute, per square centimeter by the time the energy reaches the surface of the earth. Accordingly, under ideal weather conditions each square centimeter of the reflector receives approximately 1.6 calories of heat every minute and reflects it into the small focal area, thus producing a very high concentration of energy. Since the reflector cannot be a geometrically perfect paraboloid and cannot have a reflection coefficient of unity, some energy losses are unavoidable.

The cause of a further decrease in energy density at the focal zone is illustrated in Fig. 3, in which the real path of solar radiation in a large-aperture reflector is illustrated. The image of the sun is defined by an angle of 32 minutes at any point of the reflector. The image recreated at the focal zone naturally is defined by the same angle. At a point close to the rotational axis F of the reflector, image 2 is reflected, forming cone 2_1. The intersection of the sample with cone 2_1 forms the base of the cone, which is approximately a circle of d_2 diameter. The axis of cone 2_1 is L_2. A point farther away from F reflects cone 1_1. The base of this cone is an ellipse with a major axis of d_1. Since L_1 (the axis of cone l_1) is larger than L_2, the area of ellipse d_1 is greater than the area of circle d_2. The total energy content of both cones is equal; therefore, the energy density is greater in circle d_2 than in ellipse d_1.

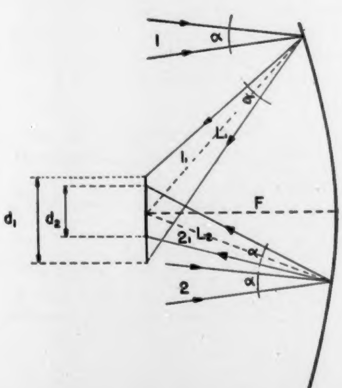

Fig. 3. Formation of the reflected image of the sun; α represents 32 minutes.

Fig. 4. Front view of the solar furnace at Fordham University.

A further temperature gradient results from the fact that the central part of the focal zone receives energy from all points of the reflector, whereas the outer part of the zone is heated only by reflection from the peripheral portions. Accordingly, the peripheral parts of the reflector make no considerable contribution to the highest temperature zone. This explains why no further rise in temperature can be obtained by increasing the aperture n above 4 (Fig. 1).

Since the central parts of the reflector contribute greatly to the high energy density, it is very unfortunate that exactly this valuable portion is shaded by the sample and the temperature-control mechanism. The completely shaded center part of the reflector is cut out, since it would not participate in the concentration of energy anyway. The opening thus obtained is used for the mounting of observation and measuring instruments.

Fordham Solar Furnace

The solar furnace at Fordham University was constructed from a 60-inch searchlight. Figure 4 is a front view of the furnace. The highly polished paraboloid mirror at the back of the furnace reflects the inverted image of buildings and trees. The observation hole with an optical pyrometer mounted in measuring position is seen at the center of the mirror. An I-beam runs across the front of the furnace. Mounted on the I-beam is a carriage that can be moved sideways with the aid of a servomotor shown at the far left side. The carriage contains the sample holder and positioning mechanism, which is activated by three servomotors. One of these motors is at the center of the photograph. Surrounding the carriage is a highly polished aluminum cylinder. This cylinder can be lowered or raised mechanically, thus decreasing or increasing the amount of radiation reaching the sample, as is explained in the discussion of Fig. 2.

The back of the furnace can be seen in Fig. 5. The optical pyrometer in the observer's hand is used for temperature measurements. The switchboard on the right side controls the operation of the servomotors. Thus the observer, without

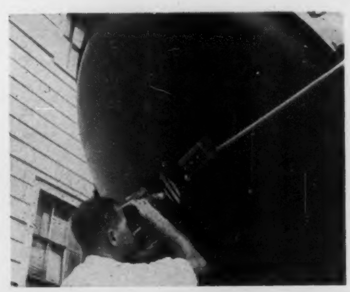

Fig. 5. Rear view of solar furnace at Fordham University, showing mounted optical pyrometer and control switches.

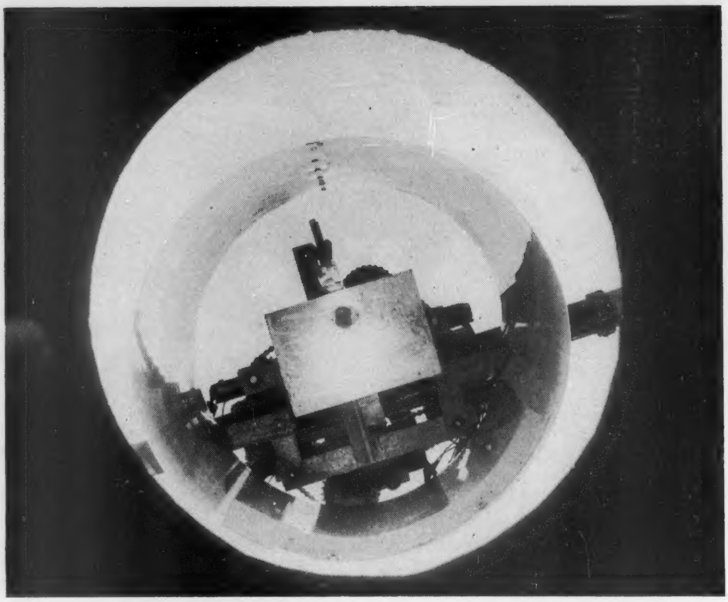

Fig. 6. Mullite sample being heated in the solar furnace.

leaving his post, can change the position of the sample in every direction, move a fresh part of it into the focal zone, and control the temperature of the focal zone. Finally, Fig. 6 is a view through the observation opening during the heating of a sample of mullite. The construction of the sample holder is visible in detail, together with the chain-sprocket system of the positioning mechanism. The bright circle on the mullite block is the heated area, and the dark spot is a cavity that was melted into the sample during a previous run.

Although the maximum temperature may be reached within a few seconds, it may be necessary for certain measurements to maintain uniform temperature at the same spot for a longer period of time. Therefore, an automatic system was developed to guide the mirror so that in its rotation it will follow the apparent motion of the sun (*3*). Solar furnaces constructed especially for this purpose are mounted on a polar axis and need only a synchronous motor for the proper rotation of the reflector.

Solar furnaces will become important tools of fundamental high-temperature research. At present, the determination at temperatures above 2000°C of the simplest physical constants—for example, melting point, boiling point, vapor pressure, and so forth—presents great difficulties in equipment and instrumentation. Measurements of specific heat and reaction rates are limited to even lower temperature regions. Studies of crystalline properties and phase changes are particularly hindered by the container problem at elevated temperatures.

The pure experimental conditions and high temperature range of the solar furnace offer a much needed relief. Some work already has been reported in this direction (*4*). Studies of electric and optical properties require single crystals of extremely high purity. If the material to be studied has a high melting point, the growing of single crystals is impossible without introducing a variable amount of impurity from the environment of conventional furnaces. Single crystals were grown in the solar furnace of Fordham University from highly refractory oxides, such as ZrO_2, without allowing them to come in contact with any material other than air. It may be worth while to mention that the solar furnace, besides being a research tool, is used at the high-temperature laboratory of Fordham University to make the hot junction bead on thermocouples. Eliminated, by this method, is the possibility of carbon contamination, which is always present during the conventional carbon-arc melting method.

No one experimental setup is available for research on solar furnaces. The investigator first has to determine the condition he wishes to maintain and then design his heating and measuring equipment accordingly. The lack of reports on experiments already completed forces every investigator to start afresh. Some consolation for this lack of interchange of information may be found in the fact that this situation is likely to produce several independent approaches to similar problems.

The importance of increasing our knowledge of the high-temperature properties of matter is not academic alone. In many fields of technology, great advances can be expected once we cross this "temperature barrier" in knowledge. Two examples will illustrate this statement. At present the temperature in the combustion chambers of jet engines is about 750°C. If this value could be increased to 1300°C, the fuel consumption of the engine would decrease to half of its present value. No engine material, however, is available to withstand such a high operating temperature. The development of a satisfactory material or combination of materials would have great military and economic importance.

A second example is found in the development of atomic power plants. The operating temperature of atomic piles is limited by the refractory properties of the construction and shielding materials. Whenever better refractory materials become available, the thermal efficiency of atomic power plants will increase greatly. In the search for better materials for the combustion chambers of jet engines, better refractories for atomic reactors, as well as much other high-temperature research work, the solar furnace may be used to great advantage.

Only a few solar furnaces are used at present for research, but considerable interest has been shown recently in this unique tool. The great potentialities of the solar furnace and the favorable reaction it has created in science and industry justify the hope that a large number of the furnaces will be constructed and used for high-temperature research.

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Low-Level Counting Methods for Isotopic Tracers

W. H. Johnston

Although the peaceful uses of atomic energy have captured the interest and stimulated the imagination of scientists throughout the world, the principal uses actually realized are the applications of radioisotopes and nuclear radiations. This is the field of radiochemistry. With the ready availability of radioisotopes made possible by the nuclear reactor, modern radiochemistry has found many applications in research, development, control, and manufacturing. In recent years, advances in radiochemical instruments and techniques have simplified measurements, extended the usefulness of radiochemical applications, and opened up new fields for the large-scale use of radioisotopes.

Perhaps the most versatile application is the use of radioisotopes as tracers. These applications range from simple bulk tagging to highly sophisticated tracings of atoms and molecules in complex chemical reactions. A few examples of bulk tracing are the tagging of sewage for tracing effluent patterns near beaches, the labeling of heating oils in underground storage for tracing leakage from pipelines, and nature's tracer experiment whereby air masses are naturally tagged with cosmic-ray-produced tritium, by means of which enterprising meteorologists can trace the movements and sources of air masses. The "bird band" tagging of the interphase between grades of oil in a pipeline, the use of gross specific activity as a measure of the degree of physical mixing or, conversely, as a volume measurement, and the timing of injected radioisotopes for monitoring flow rates are good examples of further applications that have been pioneered principally by the petroleum industry, which has been a leader in the industrial use of radiochemistry.

In the field of atom tracing, the use of radioisotopes has made possible classically "impossible" experiments—for example, the study of the kinetics of reactions at equilibrium and the tracing of a reaction mechanism by pinpointing the chemical route of a specific source atom or molecule. This has become one of the most powerful tools in the repertoire of the research chemist.

In general, these uses of tracers depend on the chemical and physical near-identity of the radioisotope to the natural element and on the unexcelled sensitivity by which radioisotopes can be detected and measured. It is in the latter category that recent advances in radiochemical instrumentation have made possible new large-scale uses for radioisotopes. This is the field of low-level counting.

The purpose of low-level counting is the detection and measurement of minimal quantities of radioisotopes in order to increase greatly the allowable dilution factors of tracer experiments. The increased dilution factors make possible the natural tracer experiments of radiocarbon dating and natural tritium studies. In a similar way, large-scale industrial tracing for product labeling and geologic tracing are made feasible. Only by low-level counting can the attendant radiation exposure be fully minimized.

In the development of low-level counting, the goals of instrumentation have been (i) to maximize the primary sensitivity of detection and (ii) to minimize the noise level of response to the background radiation from cosmic rays and from naturally occurring radioisotopes. The latter goal has involved massive shielding, electronic cancellation of many of the cosmic-ray pulses, and sometimes energy discrimination. The detectors themselves may be considered to belong in two classes, the gas-tube counters and the scintillation detectors.

Low-Level Gas-Tube Counting

The first major application of low-level counting was the work of W. F. Libby and coworkers (*1*). Their discovery of carbon-14 in nature and their establishment of the important method of radiocarbon dating required the development of the first low-level counting instruments, which were capable of measuring down to a few disintegrations per minute of this weak beta emitter per gram of carbon.

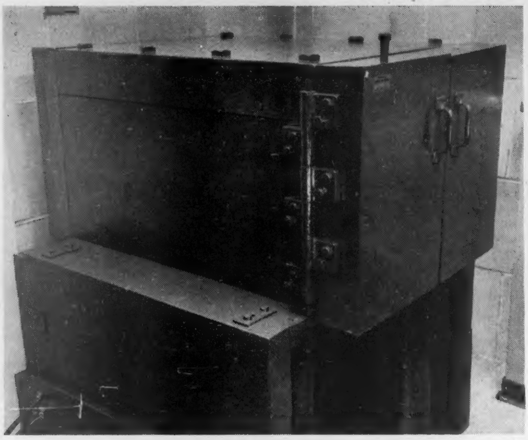
The necessary detection sensitivity was obtained by the use of the Libby screen-wall counter (*1–3*), which is discussed in a subsequent paragraph. The problem of the signal-to-noise ratio that resulted from the high background activity of this relatively large counter was solved by the use of massive shielding for gamma radiation plus electronic shielding for the mesons of the cosmic rays. These techniques of background reduction have been adopted in subsequent developments in gas-tube low-level counting.

The massive shielding usually consists of 8 inches of iron or steel. Almost as good results can be obtained with 4 inches of iron plus 4 inches of lead. A shield entirely of lead, however, is unsatisfactory, because of contamination by natural radioactivities. Of the many possible designs, one that we have found satisfactory is shown in Figs. 1 and 2 (*4*). Additional shielding is provided by an annular tank of mercury, as is shown in Fig. 2. Kulp and others have shown that placing mercury between the iron and the counter will further improve the background count by removing some of the contaminating radiation (*5*).

The problem of radioactive contamination in low-level shielding materials needs further study. Although it appears that commercial aluminum contains more radium than some types of stainless steel and that copper piping is less contaminated than most brass tubing, a general program for evaluating materials is important to an optimum design of a low-level counting assembly. An excellent start in this direction has been made by Grummitt and coworkers (*6*). An important evaluation with large samples is contemplated by E. C. Anderson at Los Alamos. With the ever-increasing use of safe, low levels of radiotracers in manufacturing and the presence of world-wide long-lived strontium-90 (*7*), it may become desirable to create a national stockpile of appropriate shielding materials.

In addition to massive shielding, it is necessary to use electronic shielding against certain components of the cosmic radiation. The mesons and some showers are detected in what has been called an "umbrella"—or, perhaps more appropriately, a "raincoat"—of Geiger counters surrounding the sample counter. A group of these counters in "mass production" in our laboratory is shown in Fig. 3. A typical installation of some of these counters surrounding a large sample counter inside the massive shield, but without the mercury shield, is illustrated in Fig. 4. During operation, the counts detected by these Geiger counters are electronically subtracted by placing them in anticoincidence with the counts

The author is on the staff of the department of chemistry at Purdue University, Lafayette, Ind. This article includes some material that was presented by Dr. Johnston at the International Conference for Peaceful Uses of Atomic Energy, Geneva, in August 1955.



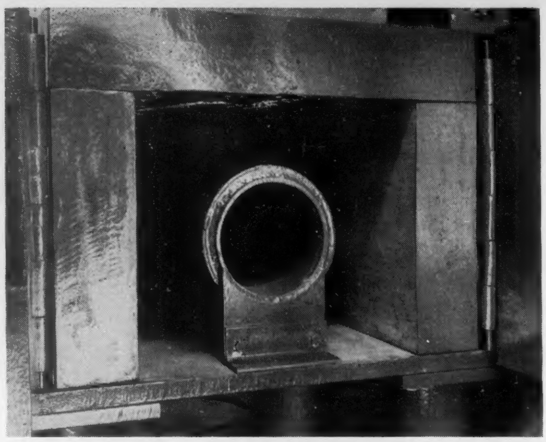


Fig. 1 (Left). Massive iron shield for low-level gas-tube counting. Fig. 2 (Right). Inside of massive shield showing the annular tank of the mercury shield.

of the central sample counter. In this arrangement, the counters of the envelope can be operated in parallel from a single high-voltage supply. A number of satisfactory circuits are available for accomplishing the anticoincidence operation (*8*, *9*). It is, of course, possible to operate more than one sample counter under a common "raincoat." Some effects of massive shields and anticoincidence shielding are summarized in Table 1.

It is interesting that the separate anticoincidence Geiger counters may be conveniently replaced by a multiple-anode annular counter with a common counting gas (*6*, *10*). It is preferable to minimize the dead volume and to allow independent operation by separating each anode compartment by a fine grid of cathode wires rather than by using the vanes of Raeth (*11*).

Screen-wall counter. The first type of gas-tube counter to be discussed is the screen-wall counter (*1*, *3*, *9*).

The sample, in solid form, is mounted on the inside surface of a cylinder that surrounds a Geiger tube. The "wall" or cathode of the Geiger tube is an open grid of wires; thus the usual absorption by a "window" is eliminated. The sensitive volume is extended to the surface of the sample by placing a suitable electric field between the sample and the screen wall or grid-cathode of the Geiger tube. The effective geometry is essentially 50 percent, and the detection of beta rays leaving the sample is essentially 100 percent.

With elemental carbon, 8 grams of sample, in which the thickness is equal to the maximum range of the beta radiation, is usually used. The self-absorption losses are therefore high. On the other hand, the large size of the sample cylinder provides an unusually large sample area of 400 square centimeters. With the optimum sample of elemental carbon, the absolute efficiency is 5.4 percent for carbon-14 (*1*).

Internal-gas counter. The second type of gas-tube counter that is important for low-level counting is the internal gas counter. In its simplest form, this counter consists of a Geiger tube with provision for placing the sample in gaseous form inside the counter as part of the counting gas. The discovery and measurement of the distribution of tritium in nature were made with this instrument (*12*). The simplicity of this counter and the associated electronics, its ease of operation, and its high efficiency, which approaches 100 percent, make this an attractive method, provided that the sample can be readily incorporated as part of the counting gas. Anderson and Levi (*13*) have shown that for carbon-14 the greater sample ac-

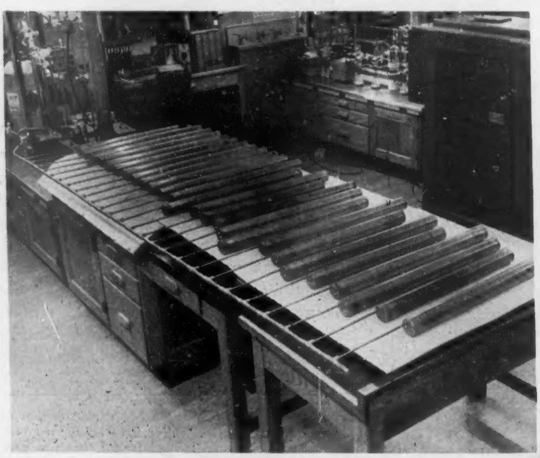


Fig. 3 (Left). "Mass production" of Geiger counters for anticoincidence shielding. Fig. 4 (Right). Anticoincidence Geiger counters surrounding sample counter in massive shield.

commodation of the screen-wall counter approximately compensates for the greater efficiency of the internal-gas Geiger counter. For less energetic beta-emitting isotopes, such as tritium, the gas counter is more efficient; for more energetic beta-emitting isotopes, the screen-wall counter is preferred. This conclusion does not apply to high-pressure proportional gas counting. On the other hand, for small samples and for many routine measurements, the internal-gas Geiger counter is preferred.

In an effort to increase the sensitivity of measurement of natural radiocarbon, DeVries and Barendsen (*14*), Suess (*15*), Crathorn (*16*), Fergusson (*17*), and Williams and coworkers (*18*) have developed the low-level, internal-gas proportional counter that uses acetylene or carbon dioxide at pressures above 1 atmosphere. The increased pressure gives increased sensitivity. The proportional region allows further reduction of the background rate by pulse-height discrimination. The theory, design, and operation of proportional counters have been covered extensively in the literature (*19*).

Early efforts to use carbon dioxide as a counting gas were unsuccessful because of electron attachment by electronegative impurities. It is necessary, therefore, to remove these impurities by a procedure such as that of Rafter (*20*) or DeVries and Barendsen (*14*). The carbon dioxide is absorbed on calcium oxide at a temperature of 700° to 750°C and is reevolved at 800° to 900°C. It has been shown by Fergusson (*17*) and others that the electronegative impurities remain on the lime. The purity requirements are very stringent. In order to keep the electron loss by attachment less than 1 percent, the concentration of oxygen must be less than 1 part in 10^6, and the concentration of chlorine must be less than 1 part in 10^7. These purity specifications and the relative complexity of the associated electronics make this beautiful method useful chiefly for such problems as radiocarbon dating of old samples. The absolute efficiency for carbon-14 is about 68 percent (*17*). Although much higher efficiencies could be obtained, the increase in background rate would increase the statistical error of the net sample count.

Foil counters. The third type of low-level gas-tube counter is the foil counter of Libby and coworkers (*21, 22*). In its simplest form, this counter is a cylindrical, thin-walled Geiger flow counter. The wall is made of an aluminum-coated plastic film of Mylar, which is less than 1 milligram per square centimeter in area density (*23*). Such a film will pass almost 75 percent of the beta radiation of carbon-14. Furthermore, the cylindrical shape provides a large surface area, in contrast to the usual commercial

Table 1. Effects of shielding and anticoincidence in the reduction of the background rate of gas-tube counters (after Anderson, *9*; and Kulp, *5*).

Shielding	Background rate (count/min)	Difference	Remarks on difference
None	450		
5 centimeters of lead	142	308	Cosmic radiation and laboratory contamination
20 centimeters (8 inches) of iron	110	32	Contamination of the lead
20 centimeters of iron plus anticoincidence	5	105	Mesons
20 centimeters of iron plus anticoincidence plus 1 inch of mercury	2	3	Contamination in iron

counter. In design, cylindrical end-pieces of plastic are fixed with respect to each other by thin brass rods. The rods and end-pieces support the plastic foil wall, which is mounted with the aluminized surface inward as the cathode. The counter gas, which is maintained very slightly above atmospheric pressure, is usually a mixture of helium and 2 percent isobutane. This gas is commercially available as "Q" gas (*24*). A foil counter and sample holder made by A. G. Schrodt are shown in Fig. 5.

When solids are to be counted with the foil counter, the sample is usually mounted on the inside of a split cylinder of plastic. The sample holder is in turn supported concentrically around the foil counter. It is not difficult to obtain about 40-percent geometry. In mounting, the sample is slurried with a volatile liquid such as methanol or ether plus a small amount of agar in alcohol. Although the operation of spreading this slurry evenly onto the sample cylinder appears to be difficult, it actually can be done easily and routinely. The spreading is done with a glass rod and spatula, and the slurry is usually dried briefly with a hair dryer or heat lamp. In the absolute assay or the precision counting of very small samples, it is more convenient to convert them to finite size by homogeneous mixing with an inert material. Schrodt and Libby (*22*) have shown that talc, acid magnesium metasilicate, is an excellent material for routine use in this manner. Of course, care must be taken to avoid radioactive contaminants such as radium. In this regard, it is interesting to note that the plastic sample cylinders should be made from ancient carbon compounds—for example, from petroleum. A cylinder containing only contemporary carbon would add about 6 counts per minute to the background rate of a counter 1.5 inches in diameter and 10 inches in length (*22*).

In counting volatile liquids with the foil counter, either refrigeration or a cover of rubber hydrochloride has to be used. If care is taken to check on fractionation effects, a liquid of low volatility can be counted after it has been absorbed in blotter paper, as a slurry in talc, or as the liquid in a shallow tray.

In counting gases with the foil counter, several modifications may be used. If a small sample is required, a modification of the 4π counter may be used in which the sample is placed in one hemisphere, which is separated by

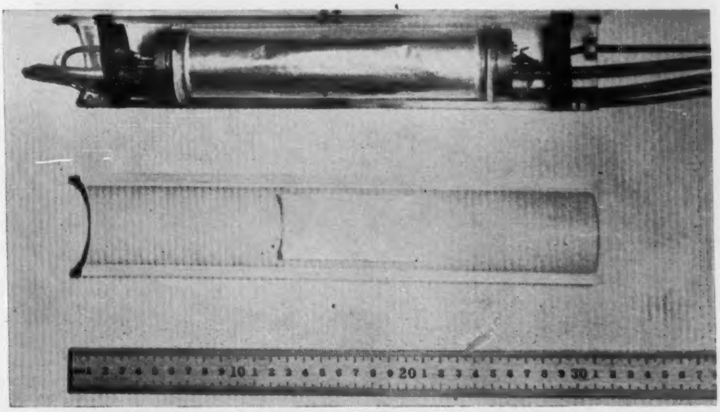


Fig. 5. Foil counter and sample holders.

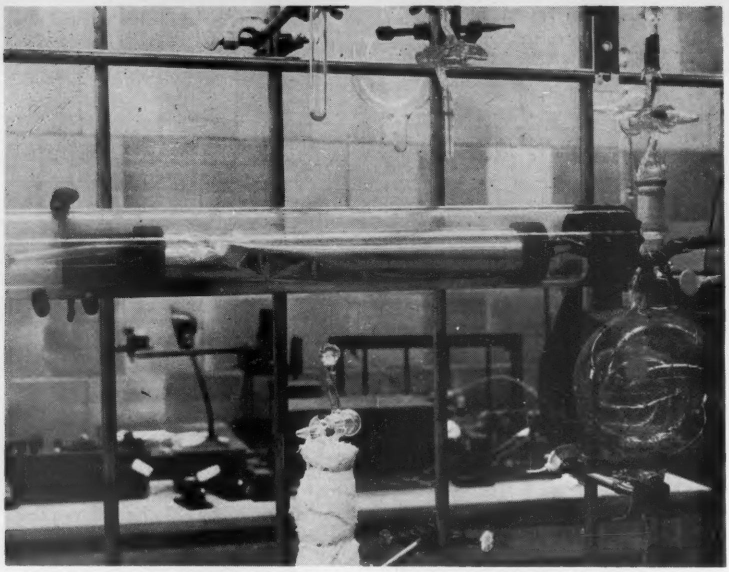


Fig. 6. The annular foil counter for gas samples.

Mylar foil from the other hemisphere, which operates as a Geiger counter with "Q" gas. For larger samples and for greater sensitivity, a cylindrical foil counter may be mounted inside a metal or glass jacket, as is shown in Fig. 6. The sample to be counted is introduced by flushing it into the annular space; alternatively, the annular space may be evacuated simultaneously with the counter before filling. During these operations, a simple mercury U-tube may be used to warn against a dangerous pressure differential. The relative simplicity of instrumentation and the lack of rigid purity specifications on the gas sample make this method desirable for many applications.

An interesting proportional counter using the thin foil between sample and detector is the Sugarman counter (*25, 26*). This device is a methane-flow proportional counter with a foil window. The precision design and the segregation of the counter gas give remarkably stable and reproducible operation. Plateaus are long, flat, and reproducible over years of operation; counts of a sample taken on two counters agree within statistics to 0.1 percent (*27*). For moderate-level counting and ordinary low-level counting of strong beta emitters, this counter is very useful.

Recently the foil window was combined with a multiple anode-wire cathode flow counter to provide a flat counter of active area of 400 square centimeters (*28*). For many types of samples, this counter, which we call a "sandwich" foil counter, simplifies sample preparation and mounting and provides the increased sensitivity of detection that is needed for routine low-level counting. By accurate leveling of the large sample holder, liquid samples can be conveniently measured. In the case of a weak beta emitter such as carbon-14, it is easy to operate with an "infinite" thickness of liquid and, in many experiments, to avoid the chemical conversions frequently needed with an ordinary area detector. A "sandwich" foil counter and sample tray is shown in Fig. 7.

The various gas-tube counters described here are compared and summarized following a discussion of the low-level scintillation detectors.

Low-Level Scintillation Counting

In recent years, improvements in photomultiplier tubes (*29*) have made possible low-level counting with scintillation devices. In general, the advantages of scintillation detectors over gas-tube counters depend on the greater stopping power of a crystal for gamma rays and on the larger inherent sample-handling potential of liquid scintillators for beta radiation. The principles of the scintillation counter have been reviewed extensively (*29, 30*). The applications to low-level counting are discussed here in terms of the low-level sodium iodide scintillation spectrometer for gamma radiation and the multiple-channel liquid scintillation spectrometer for beta radiation. The single-channel liquid scintillator is mentioned briefly.

In low-level gas-tube counting, the reduction of the background rate was accomplished by massive shielding and by anticoincidence meson shielding. In low-level scintillation counting, some massive shielding is also used. In addition, pulse-height analysis by at least two discriminators electronically discards the meson counts and, in many applications, the background events of energy different from the counted pulses. In view of the energy discrimination, less massive shielding is required in many applications. The most satisfactory shielding material is mercury (*31, 32*).

Low-level scintillation spectrometer. For low-level gamma counting, an ordinary sodium iodide scintillation spectrometer is modified in two ways. First,

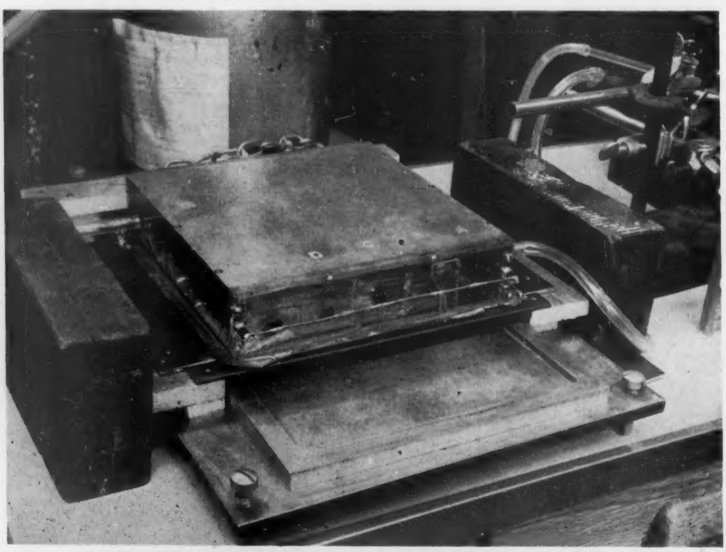


Fig. 7. A large area multiple-anode foil counter ("sandwich" counter).

the crystal is surrounded with the mercury shield. Second, the electronic circuits are designed for maximum stability. It should be possible to focus on a photopeak and remain there during at least 48 hours of counting. Particular attention must be given to the long-term stability of the high-voltage supply that operates the photomultiplier tube. For many measurements, this tube should have a low thermionic noise rate at room temperature.

Several studies have been made using instruments of this type. Arnold's discovery of beryllium-7 in nature (*33*) and his measurements of lutetium-176 (*34*) and our tracer study with chromium-51 (*35*) are examples. In the latter study, with only moderate attention to low-level detection, the counting rates were 20 times higher with the scintillation spectrometer than with a Geiger counter. Another study was made using iodine-131 for the measurement of a very slow reaction (*36*). This apparatus is shown in Figs. 8 and 9. The mercury shield is clearly visible; in Fig. 9, it contains a liquid sample. When a reasonable amount of this tracer was used, the limit of detection with the low-level scintillation spectrometer gave a theoretical limit of greater than 10^6 years for measurable half-reaction. In this study, the counting rate of a liquid sample containing the iodine-131 was 100 times greater in the scintillation spectrometer than it was in a Geiger counter of the same size and geometry as the sodium iodide crystal. Of course, the efficiency of detection will vary with the energy of the gamma radiation. At energies up to 200,000 electron volts, the efficiency of a 1-inch crystal is 100 percent; at 300,000 electron volts, it is about 75 percent; and at 1 million electron volts, it is approximately 10 percent (*37*). Of course, an efficiency approaching 100 percent can be obtained with any reasonable energy by the use of a large enough crystal.

Fig. 8. A low-level scintillation spectrometer.

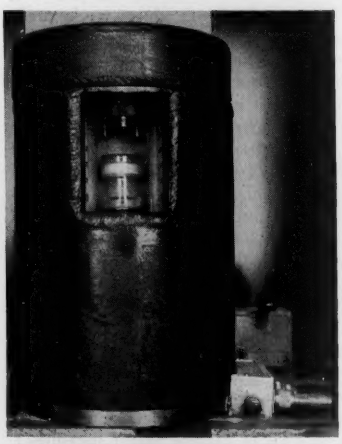


Fig. 9. Mercury shield and sample holder of the low-level scintillation spectrometer.

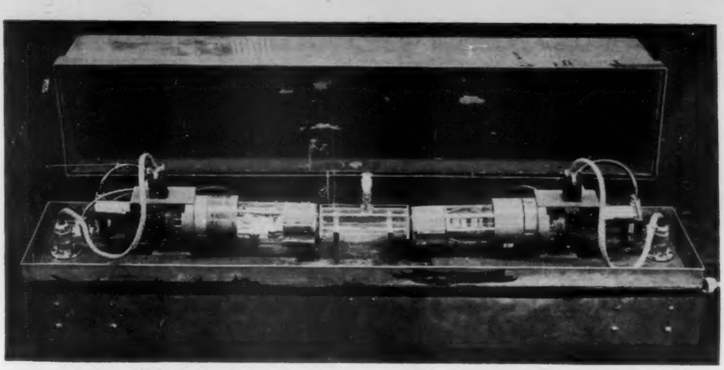


Fig. 10. A simple dual-channel liquid scintillator.

Liquid scintillators. The development of low-level liquid scintillators was carried out chiefly by Hayes and his collaborators at Los Alamos (*38, 39*) and by Arnold at the University of Chicago (*39, 40*). In liquid scintillation counting, the sample is simply incorporated in solution with a liquid scintillator. This arrangement gives essentially 100 percent geometry and no self-absorption. Unfortunately, the decreased efficiency of liquid scintillators over solid scintillators and the desirability of detecting the lower energy pulses of beta spectra require the measurement of "equivalent electron" pulses or those pulses that result from single-electron emission from the photocathode of the photomultiplier tube. These pulses, however, are indistinguishable in size from the thermionic pulses of the tube. This problem is solved by the use of two photomultipliers looking at the solution. By placing the pulses from the two channels in coincidence, it is possible to accomplish a large discrimination against the separate random thermionic pulses of each tube. In addition, some cooling is required, usually to a temperature of –20°C. Such an arrangement essentially eliminates tube noise provided that fast electronic circuits are used (*41*). Our apparatus is shown in Fig. 10.

Although the choice of the liquid-phosphor solution depends somewhat on the choice of the photomultiplier, an excellent solution consists of 2,5 diphenyloxazole as the primary solute and 1,4 di(5-phenyl-2-oxazolyl)benzene as the secondary solute or wave-length shifter in toluene. The sample to be counted is incorporated in this mixture and must not quench the scintillation. Although solutions can be prepared to count almost any beta emitter, the cost of this instrument is not usually justified except for the measurement of weak beta emitters. Thus the counting of tritium and carbon-14 has received much attention (*26, 38–42*). Tritium can be counted in the form of water added with alcohol to the afore-mentioned solution or, alternatively, by the procedure of Nir (*43*). Here the THO is mixed with fuming sulfuric acid (or SO_3) and toluene. The tritium enters the toluene by exchange, and the latter is separated and used for the solvent of the scintillation solution. With carbon-14, the choice of this method may depend on the chemical form of the sample. One of the advantages of the multiple-channel, liquid scintillator is the unlimited size of the sample that can be accommodated in principle. Thus Reines and his collaborators at Los Alamos have constructed an instrument containing 300 liters of scintillation solution (*44*). In this counter, which was used in a search for direct evidence of a neutrino reaction, 90 photomultipliers were used to detect the scintillation pulses. An even larger liquid scintillator assembly was used by this group in the recent observations of a neutrino-induced reaction.

In regard to the sensitivity of the dual-

channel liquid scintillator, Arnold obtains an absolute efficiency for carbon-14 of about 60 percent for a 30-milliliter solution containing approximately 50 mole percent of carbon (*45*). The counting rate was 70 counts per minute against a background of 12 counts per minute. In the same instrument, the efficiency for tritium was much less, approaching 25 percent.

An interesting technique developed by Hayes and others at Los Alamos for measuring solid samples is to suspend a fine precipitate in a liquid scintillator. Although surprisingly high efficiencies are obtained, the problem of decreasing counting rate with settling indicates a preference for the technique of Helf and White in which the suspension is stabilized by the formation of a gel (*46*).

The possibility of using a single-channel liquid scintillator for low-level counting has been examined by Pringle and coworkers with considerable success in radiocarbon dating (*42*). It is clear, however, that the photomultiplier tubes used were better in terms of lower thermionic noise than any ordinarily available today. The widespread use of this method for carbon-14 must await the development of a better commercial photomultiplier tube.

One interesting potential of both liquid and solid scintillation counting is the possibility of multiple tracers. For example, with a sodium iodide scintillation spectrometer, the photopeaks of such tracers as chromium-51 and iron-59 can be separated (*47*). With the liquid scintillator, tritium and carbon-14 can be counted simultaneously (*26*).

Applications and Conclusions

In choosing a low-level counting method for a specific job, a number of factors must be considered. Some of these are the type and energy of the radiation, the size of the samples that are available, and the degree of sensitivity required. In Table 2, the low-level instruments for beta counting are summarized according to these factors. Weak beta emitters are nuclides such as carbon-14 and sulfur-35; strong beta emitters are phosphorus-32 and silver-111. Tritium is not included in Table 2. In tracer studies with tritium, the suggested method is the internal-gas counter. In moderately low level counting of tritiated water, a convenient procedure is to count as acetylene gas (*48*). In extremely low level counting, hydrogen is counted in a Geiger counter (*12*). In special cases a dual-channel liquid scintillator can be used, or else the method of Bernstein and Ballantine can be modified to include anticoincidence background reduction (*49*).

For counting a gamma emitter, the low-level scintillation spectrometer is used. In cases where the tracer emits both beta and gamma radiation, it is sometimes more convenient to measure the gamma radiation with this instrument, because of self-absorption of the beta radiation.

The present-day commercial availability of low-level counters is unsatisfactory, but it is steadily improving. Several companies are offering several of these instruments or their components. A complete gas-tube low-level counting assembly with provision for Geiger and proportional counting in our laboratory is shown in Fig. 11. A similar assembly will be offered soon by at least one manufacturer (*32*).

Tracer Applications and Low-Level Counting

Several reviews indicate the great diversity of tracer applications (*50*). In research, the chief studies involve self-diffusion, reaction mechanisms, surface phenomena, isotope effects, kinetics, and isotopic-exchange reactions. In all of these applications, low-level counting is potentially valuable. In some cases, the increased sensitivity is important scientifically. In other cases, the total amount of radioactive material needed can be decreased.

The use of industrial tracers for development and control is in an early stage of development. There are many direct applications of low-level counting in the many uses of tracers for large-scale labeling of products and in the tracing of oil fields. A great variety of radioisotopes provides valuable methods for measuring flow rates, volumes, flow patterns, mixing rates, and chemical arrangements and for making identifications. Recently some of these techniques were described for use in refinery control (*51*). Although some of these uses cannot tolerate the long counting times of extremely low level counting, the principles of low-level counting are important to all these applications.

One of the obstacles to the large-scale industrial use of tracers is the problem of residual radioactivity in the final product. One solution to this problem is the use of tracers of short half-life. By extraction techniques, short-lived daughter products can be conveniently obtained from long-lived parents. Thus, iodine-132 (half-life, 2.4 hours) can be "milked" from tellurium-132 (half-life, 78 hours). Such procedures can be made automatic by the use of continuous extraction methods. Thus, in the control of flow patterns and mixing rates, one could use a steady-state injection of the short-lived tracer.

Another solution to the problem of the residual radioactivity is the use of low levels of tracers. It is here that low-level counting is essential. A number of tracer studies using carbon-14 have counted the final samples as barium carbonate by using an ordinary thin-window Geiger counter. Under these conditions, a sample of contemporary carbon would be expected to show the immeasurable counting rate of 0.006 count per minute against a background of 20 to 50 counts per minute. With low-level counting, the same natural carbon would measure 7 to 150 counts per minute against background rates of 2 to 30 counts per min-

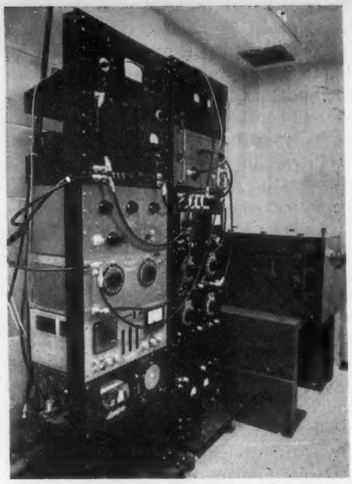


Fig. 11. A complete low-level counting assembly.

Table 2. Low-level beta counting.

Availability of sample	Low-level counting	Suggested counter	
		Weak beta radiation*	Strong beta radiation
Small	Moderate	Foil Geiger counter	Sugarman proportional counter
Small	Extreme	Internal gas Geiger counter	Libby screen-wall counter
Large	Moderate	Foil Geiger counter	Foil Geiger counter or Sugarman proportional counter
Large	Extreme	Dual-channel liquid scintillator or internal gas proportional counter	Libby screen-wall counter or multiple-channel liquid scintillator

* For example, carbon-14 or sulfur-35 (not including tritium).

ute. In this example, low-level counting would make possible a factor of 10^{-4} or better in the necessary residual radioactivity.

One of the questions concerning the realization of the potential future of large-scale industrial tracers is the danger of the residual radioactivity to the consumer. The natural tracer experiments with tritium and carbon-14 indicate the answer. Consider the use of tritium as a tracer in the petroleum industry—for example, in the tagging of oil for identification of leaks from underground storage. Even if a world output of 7×10^9 barrels of oil per year were tagged at a measurable level of 10^{-6} curie per barrel, the steady-state increase in the world inventory of tritium would be less than 1 percent. Even the maximum transients in water would be less than 0.5 percent of the maximum permissible amount (*52*) of tritium in water. In the case of carbon-14, the entire world output of sugar could be regularly tagged at the easily measurable level of 10^{-11} curie per gram of carbon with a corresponding maximum increase of only 0.1 percent in the world inventory of radiocarbon. It is clear that with reasonable care and modern instrumentation, safe large-scale tracer operations can be realized.

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Electronics for Measuring Human Motions

Jay Goldman and Gerald Nadler

Measuring the performance of people at various work activities has been an essential task in many fields, both academic and industrial. Physiology, psychology, and physical education are some of the academic endeavors requiring a measure of output or performance of persons for purposes of studying relationships to various factors. For example, the physiologist wants to measure the direct result of some muscular activity that he may be studying, in order to correlate the two results. The psychologist in biomechanics wants to measure the output of a subject when he is trying to design man-machine relationships. The physical educationist should be able to make a complete measurement of every part of a tennis or golf swing.

Although industrial engineering is both an industrial function and an academic pursuit, most of the research problems stem in some way from problems in the industrial situation. A review of some of these problems will point out the essential necessity for measuring operator performance in industry and how the lack of suitable measurements has led to the development of a device which should help all activities concerned with human performance.

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Background of Work Measurement

In today's highly competitive economy, a progressive enterprise must attempt to perform its operating function in the most effective manner possible. Work-measurement techniques (of which time study is one) are among the most useful tools available to modern managements. Work measurement establishes the standard time required to perform jobs. The success or failure of enterprises involving literally billions of dollars rests on bases that consist, to some major extent, of these standard times.

Both management and labor have a great stake in work-measurement techniques. Work measurement affects all types of people, presidents and workers, supervisors and union stewards. In this sense, the utilization of work measurement is dependent on human beings as well as on its projected technical application. If there are any inaccuracies or inconsistencies in the strictly technical sense, there is a large area for the development of friction between the parties (usually management) applying and using the techniques and the parties (usually workers and unions) to which the techniques are applied. Such friction can be a major cause of costly strikes, for example, the recent Westinghouse situation.

More labor-management cooperation can be expected as a natural result of management's awareness of general problems in human relations and, probably just as important, of the developments of technical research in the field of work measurement. More cooperation can be expected between any parties when the basis for their mutual understanding is broader. This is the purpose behind much work-measurement research. The lack of accurate work-measurement theories, information, and measuring devices on which to base many of the decisions needed in the labor-management area has caused much of the difficulty that exists between labor and management.

Management itself needs the time standard to form the base upon which many operating procedures are built. Such procedures include balancing work (and production lines), determining equipment requirements and manpower requirements, planning production processes and layouts, planning costs of new and revised products, controlling production, and controlling the costs of production. Of course, good wage-incentive programs require good work measurement. This list can be expanded many times and is limited only by the imagination and ingenuity of the organization.

Although some of these functions can be accomplished without work measurement, they are not usually performed as satisfactorily by other means alone as with the aid of these techniques, even though work measurement involves some errors. An end-result is only as valid as the base from which it is obtained. A high degree of accuracy is necessary for all work-measurement situations, but techniques should provide a way to make these measurements as accurate as possible, and they should also provide a base reference point for the estimation of errors.

Many factors affect the performance of a human being on the job, but the most important factors are centered in the human being himself. Putting aside other factors, it is readily apparent that it is now impossible to measure all the human causal factors affecting the performance of a person. The measurements, therefore, are made of the effects of these causes. The speed of motion is one of these effects, and it is the one usually measured. To measure accurately speed of motion, the values of velocity, acceleration, deceleration, position, distance, and direction for all possible motions the body members can perform must be obtained. No measuring device has been available for making all these measurements.

In designing a new device for making these measurements, certain new factors had to be considered. For example, the measurements must be three-dimensional; attachment to the body member must be small and light; devices must operate under all factory conditions; the range of velocities measured may be small (0 to 10 feet per second), while the range of acceleration and deceleration may be large; and measurement systems must be designed to give immediate results.

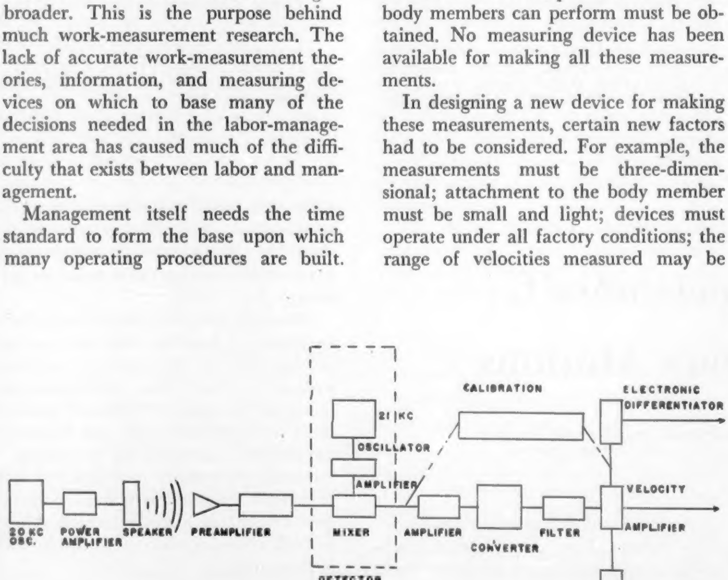

Fig. 1. Block diagram for a single channel of UNOPAR.

Development of Work-Measurement Device

After careful consideration of all possible measuring techniques, we decided that the Doppler effect with sound as the radiation medium presented the fewest formidable obstacles for successful development of a work-measurement device. The device designed is called a Universal Operator Performance Analyzer (UNOPAR). Its operating frequency of 20,000 cycles per second is just above the threshold of hearing at normal levels of intensity. This frequency helped overcome the interference problem from other noises within the factory. The sound-emitting source must be attached to a body member, but eventually the size of this source will be no longer than a wrist watch, or even a ring on a finger.

Three microphones, oriented in three planes with the directional axis of each perpendicular to the directional axis of the others measure motions in the three planes. Each microphone receives its component portion of the sound waves projected from the speaker on the body member moving toward or away from the microphone. This system provides a variable axis of reference, since the three planes can be rotated. This permits flexibility to circumvent obstacles to the path of transmission and to permit use of overhead space in industrial situations.

Because of the Doppler effect, a transmitting source of sound that is in motion relative to a stationary receiver provides an apparent frequency of sound at the receiver that varies directly with the velocity of the source. Motion toward the stationary receiver will increase the frequency received, and motions away from the stationary receiver will decrease the frequency received.

According to the Doppler effect, only one-plane motions toward or away from any receiver should be registered as true speaker motion. This presents a practical operating problem, for the receiver is a fixed point of reference, and the speaker is a variable one. When the speaker is moving in a path perpendicular to the microphone, the direct distance between the speaker and the microphone varies. The greater the variability of this distance, the greater the error. For practical application, the motion of the speaker is assumed to be confined within a 1-yard cube, and the microphones are placed 10 feet away from the center of this cube, so that the maximum possible error will not exceed 1 percent of the true motion.

Operating Procedure

The basic operating procedure of UNOPAR begins with the generation of the operating frequency of 20,000 cycles per second. As is indicated in the block diagram (Fig. 1), this 20-kilocycle signal is sent to a power amplifier and then to the speaker. Most of the limited research work performed to date has been done by moving a speaker rather than by attaching a speaker to a moving body member. Soon the latter procedure will be used. If more than one body member is involved in an operation, different frequency signals could be used to differentiate the different members involved. At present, a relatively small electrostatic speaker is being used, but a smaller speaker should be available soon.

The perpendicular factors of the frequency changes caused by the motion of the speaker are picked up by the three microphones. The block diagram (Fig. 1) shows only one microphone and its corresponding circuit; the same circuitry would be used for the other two microphones. When the speaker is in motion, the frequency of the sound received at the microphone will be 20 kilocycles per second plus or minus the Doppler difference. Since the voltage level of this received signal is quite low (15 microvolts), it is sent through a preamplifier composed of five tuned amplifier stages. The 20-kilocycle signal, plus or minus Doppler-difference frequency, is mixed with a 21-kilocycle reference signal (generated by a crystal-controlled oscillator). A 1-kilocycle signal, plus or minus the Doppler-difference frequency, is obtained. This is a usable signal for conversion to voltage. It is sent through a tuned amplifier stage to increase the voltage and then to the converter.

In the converter, the sine wave is first changed to a square wave. This is done so that the signal which drives the thyratron (2D21) is independent of the amplitude of the incoming signal. In addition, the thyratron must be driven by a signal of high amplitude and short time duration. This can be obtained by differentiating the square wave, but it cannot be obtained directly from the sine wave. These pips are sent into the thyratron whose circuit is arranged so that its d-c voltage output is directly proportional to the frequency of the input. Since some of the input pulses remain on the output voltage, the signal is sent through a π section filter. This d-c voltage is directly proportional to the velocity of the speaker. (The d-c output voltage is proportional to the input frequency, and the input frequency is proportional to the velocity of the speaker through the Doppler-effect relationship.)

The d-c voltage is sent to a d-c amplifier to increase the voltage and then to the velocity recorder. The amplified d-c voltage is also sent to an electronic differentiator, whose output voltage is proportional to the acceleration and deceleration of the speaker. This signal is sent to the acceleration-deceleration recorder. The amplified "velocity" voltage is also sent to an electronic integrator whose output voltage is proportional to the displacement of the speaker. This signal is sent to the displacement recorder.

Fig. 2. Test setup for determining UNOPAR reliability of measurement for one-plane motions.

Direction of the motion is determined from the voltage variations above or below the voltage output of the 1-kilocycle signal input. A voltage larger than this indicates a motion toward the microphone, and a smaller voltage indicates motion away from the microphone.

For any motion, three records of velocity, three of acceleration-deceleration, and three of displacement are obtained. The three records for a given measurement unit are combined into the absolute total by electronic vector summation. The calibration circuitry is designed to generate sine-wave signals of the proper frequency to check the velocity and acceleration maximum displacement values.

A 12-channel d-c oscillographic recorder is used to plot each one of the individual factors and the resultant components of velocity, acceleration-deceleration, and displacement. The recorder is capable of plotting information at a constant maximum speed of 125 millimeters per second (5 inches per second), thus providing an accurate timing record for every motion.

The present electronic equipment and recorders are fairly large. Development of the equipment indicates that there will be a sizable reduction in the amount, size, and weight of the necessary components.

Accuracy

Tests for reliability of measurement were made for one-plane motions (there is no criterion for three plane motions) with an accelerometer as the criterion source. The test setup is shown in Fig. 2. Chi-square and correlation were used to check the size and shape of UNOPAR, criterion velocity, and acceleration-deceleration plots. Chi-square probabilities of 0.99 and above and correlations of 0.99 and above were obtained, indicating excellent fits for the curves. Additional verifications were made with the standard deviation for percentage of error from the accelerometer plot for the maximum (peak) velocity, maximum acceleration-deceleration, and time for a series of motions. For velocity, the standard deviation was 1.08 percent; for acceleration-deceleration, 2.17 percent; for time from velocity, 1.06 percent; and for time from acceleration, 2.79 percent. These results indicate excellent measurements (there is some evidence that part of the errors obtained were due to the accelerometers, not to UNOPAR).

An indication of the type of information available through the use of UNOPAR is shown in Fig. 3. The motion was performed on the test set-up of Fig. 2, and the motion was stopped by the support at the end of the motion. The velocity plot in Fig. 3 shows the direct response of the device to a motion of this type.

Uses

Many work-measurement benefits can be found in the application of UNOPAR to problems of studying operator performance. Information about every motion will help establish the concept of a standard or normal level of performance.

Fig. 3. Drawing of a tape that recorded the motion of the test speaker in one plane. The speaker was at rest at the left. As the speaker started to move, the velocity charted increased rapidly. There was a very slight slowdown of velocity until the speaker hit the barrier. At this point the velocity dropped immediately, and the slight rebounds of the hands and speaker are indicated by the wavy motions after the drop. The motion was recorded on the tape running at the fastest speed.

Much work must be done to combine all these measurements into an over-all concept of operator performance. However, through experimentation and research, this problem may be solved in the near future, for UNOPAR now makes measurements that could not even be roughly approximated in the past.

Other problems dealing with work, or with what a human being does, may be solved with the aid of UNOPAR. A brief review of some possibilities will show the widespread adaptability of the measurements. [For a complete discussion of all aspects of the UNOPAR and its potential uses, see G. Nadler, *Motion and Time Study* (McGraw-Hill, New York, 1955), pp. 417–428.] The instrument may not be capable of summarily solving all problems outlined in subsequent paragraphs, but at least much light may be shed on these problems.

Let it be assumed that a time standard is established for a definite method and that it is essential to accurately describe the method. Many disputes arise today because of the use of qualitative methods of description. It is difficult to determine when a change in time standards is fair if there are no ways of computing values of percentage variations of methods. Quantitative measurements from UNOPAR may help to establish a procedure for detecting changes in method.

If the permanent record of displacement and position gives new information about motions, motion patterns, and motion paths, better decisions can be made about the correct motions for an operation as well as about the correct sequence of these motions.

Frequently, two operators, using what is considered to be the same method, differ considerably in performance. An accurate measurement of their motions may disclose subtle differences in performance that are not readily observable. With the information about individuals and individual differences obtained by using UNOPAR, it may be possible to train poor operators to improve their performances.

Time units on the UNOPAR records are as small as 0.000133 minute, measured on a recorder tape moving at a speed of 125 millimeters per second at 1-millimeter intervals. Even smaller time units can be obtained. When this level of accuracy is not needed, a slower speed can be used. Measurement of the elapsed time required to complete a motion or an operation is a great deal more accurate than usual timing procedures, especially since full actual motions are recorded, not just end-points determined through an individual's reaction time and other errors.

The difficulty of an operation affects the pace of an operator. Because difficulty and pace are interrelated, UNOPAR can help obtain accurate information about difficulty.

There are many standard data systems (compilation of past standard time information for application purposes without direct study) in use today. There is some controversy about the validity of these systems. Because times for motions or groups of motions form the bases for these systems, UNOPAR can check into their assumptions.

Even if there were no other advantages to be gained through the use of UNOPAR, one of the most readily apparent is that exact information about each and every motion of each cycle is recorded, whereas other procedures of motion and time study or work simplification and measurement obtain only over-all information. The ability to provide specific information is a basic requirement for any good measurement procedure.

However, the use of UNOPAR will not be restricted to industrial engineering alone. As is pointed out in a foregoing section, measurement of human performance is needed in other areas, such as psychology, physiology, sociology, biomechanics, education, and physical education. Within the near future, UNOPAR should help solve many of the problems in each of these areas by providing accurate information about motions and performance.

With this objective information, management and labor should benefit through more accurate information for all the areas in which time standards are important.

It is important to warn that UNOPAR has not been fully developed and that, when it is, it may not be capable of everything expected of it. However, it represents such a radical change in the concept of measurement of human performance that we think it can be expected to revolutionize many aspects of industrial engineering. We believe that the information available from UNOPAR is so much more accurate than that available from other procedures or techniques that much more can be learned about the performance of a human being than ever before.

Phase Microscopy 1954–56

Oscar W. Richards

Phase microscopy has become a recognized standard method. Few publications now refer to it in the title, and a complete listing of papers is no longer possible. Some of the uses of phase microscopy in the first 2 years of the second decade since we demonstrated the first American instrument (*1*) are summarized here as well as a few papers missed in the preview review (*2*). Details on the function and use of the instrument in various fields are available (*2, 3*).

General, Theory, and Instruments

While the previous review was in press, Wilska (*4*) described the new Reichert Anoptral phase microscope, which is unique in using a less reflecting material than evaporated metal for the diffraction plate. Bright contrast is used so that differences in the refractive power of the specimen are better revealed (*5*). The outside diameter of the diffraction plate is made larger for increased resolution. The image is slightly yellowish, less harsh, has less glare, and photographs well, as is shown in the varied photomicrographs of Schüller (*6*).

A bibliography has been published by the firm of Winkel (*7*), Fröhlich has summarized some German and Swiss work (*8*), and information on the theory and use of phase is included in the symposium reported by Françon (*9*). General discussions in Dutch have appeared by Bok (*10*) and Bogaerdti (*11*). Czerny (*12*) expresses amazement that phase was not discovered between Abbe and Zernike, apparently unaware of the work of Bratucheck and of Conrady and Rheinberg (*13*). Zernike (*14*) tells how he discovered phase about 1930, and some general and medical applications are mentioned by Crossmon (*15*).

Wolter (*16*) summarizes much of his work and relates phase to *schlieren* and other methods, and Barer (*17*) summa-

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rizes his vector theory of phase microscopy along with some useful historical information. The intensity distribution of the light in the image of a rectangular object for commercial phase microscopes is calculated by Schmidt (*18*), and optimal values of retardation and size of annulus are deduced and confirmed by experimental measurements. A wedge-shaped collodion test object is proposed by Menzel (*19*) for phase contrast. Precision absolute phase measurements are reported by Fleischmann and Wegener (*20*). Kahn (*21*) derives conditions from Maxwell's equations which indicate that no restriction need be placed on the shape of the object to be examined. Improved phase and interference microscopy are discussed by Wolter (*22*), who uses polarization methods to measure phase and amplitude changes. Thus, a quantitative phase microscopy may become possible. Räntsch has tested two methods for obtaining maximal phase contrast and, after comparing amplitude and phase effects, concludes that variable amplitude and a 90° phase shift would give best contrast in a variable phase microscope (*23*).

The Zeiss-Winkel phase accessories are described by Flügge (*24*), and Kawiak (*25*) describes Zeiss equipment in Polish. Matthews (*26*) uses a hollow-cone method for illuminating the phase plate, which can be changed to darkfield illumination.

The patent literature has increased considerably. Bennett (*27*) has a patent on a method for variable phase microscopy. Françon *et al.* (*28*) have included phase in a catoptric system. Heine (*29*) obtains colored phase contrast by using colors in the conjugate and complimentary areas, and L. Leitz (*30*) by means of a tricolor filter ahead of a darkfield condenser and the use of a tapered diffraction plate. Kavanagh (*31*) patented a method using separate paths for the deviated and undeviated light as means for varying the phase contrast. E. Leitz G. m. b. H. (*32*) have a patent for polarized light in a phase vertical illuminator, and Locquin (*33*) has one for variable phase together with color phase contrast. The variation in the color of the light is accomplished by tilting an interference filter. Menzies (*34*) has a phase system using alternate sectors of opaque and transparent material. Variable phase patents include a wedge system of Osterberg (*35*) and Bennett and Kavanagh's system combining an iris, patch stop, and an auxiliary lens (*36*).

A compact photomicrographic apparatus with electronic flash illumination is described by Jarrett (*37*) for phase pictures of moving specimens. Wied (*38*) combines a Micro Ibso attachment with a Linhof Technica camera having a Polaroid back in order to obtain rapidly finished pictures with the phase microscope. A flexible motion picture installation with electronic timing is described by Robineaux (*39*).

Phase Combined with Other Methods of Microscopy

The increasing tendency to use several methods of microscopy on appropriate problems is further noted. Some examples are cited here, and others mentioned under their appropriate topics. Wolter discusses phase and interference microscopy (*40*).

Locquin (*41*) appears to be the first to use phase methods in an electron microscope; he achieves the equivalent of a B- phase plate that reveals contrast with changes of specimen thickness. Combinations of phase and electron microscopy are used by Becher and Hoegen (*42*) to examine the action of hyaluronidase on individual cells. Borysko and Sapranauskas (*43*) combine the methods for the study of tissue cultures with time-lapse cinephotomicrographic checks. *Penicillium* is examined with phase and electron microscopes by Bringmann (*44*). De *et al.* (*45*) use both microscopes to study the nuclear apparatus of *Escherichia coli*. Movements of the centrosome are followed, as well as the change in contrast of the parts of the cells. Electron and phase instruments are used by Odor (*46*) to examine rat mesothelium, by Weinreb and Harman (*47*) for mitochondria, by Man'i (*48*) to investigate hemolysis, by Hodge (*49*) on dipteran flight muscles, by De Marsh and Kautz (*50*) on sternal biopsy cells, and by Hartroft (*51*) on renal juxtaglomerular cells. A new type of contrast, called interchromatic contrast by Locquin (*52*), is obtained with the electron microscope and is partly phase and partly new.

Phase and fluorescence microscopy are combined in a thorough study of the developing tooth by Hals (*53*). Mellors *et al.* (*54*) use fluorescence microscopy to locate antibodies in tissues and phase for detailed study. Phase microscopy is used by Krueger (*55*) to orient cellular material for ultraviolet absorption studies of salivary gland chromosomes.

General Methods

Phase microscopy is reported to be useful in the study of thick (30 to 80 microns) sections of injection preparations (Kleiss, *56*). Spodograms reveal more detail with phase than they do with ordinary microscopy, according to Godlewski (*57*). Haselmann *et al.* (*58*) describe a stage for holding a mouse for studies of secretion in the viscera and pancreas.

A microculture cell for growing bacteria has been devised by Devignat (*59*) and a perfusion chamber by Schwöbel (*60*), both for use with the phase microscope.

Lowenthal (*61*) reports that television phase microscopy gives added contrast and is useful for the examination of living leucocytes, and Hinselmann (*62*) uses television phase culposcopy.

Barer and Joseph (*63*) provide details on the theory and use of phase microrefractometry for measuring the refractive index of components of living cells. They match the index against a standard serum albumen solution, either directly, or by proportions of cells in a population showing the reversal in contrast. Dry and wet weights may be calculated from the index data, and when they are used with the interference microscope, some interchecking is possible. Ingelstam (*64*) applies and extends this new branch of phase microscopy. Gelatin is recommended as a reference mounting medium by Müller (*65*), for 8- to 80-percent solutions have refractive indices from 1.350 to 1.421.

The change of appearance of a detail from bright to dark contrast as the refractive index of the surround is greater or less than the detail (*3*) provides information on the uniformity of materials and the purity of isolates (*55, 66*).

Mounting media that may be useful in phase microscopy are Ferrari's (*67*) cumarone-indene resin (*n*, 1,650); Fleming's (*68*) improved Naphthrax; Salmon's (*69*) polyvinyl mixture (*n*, 1.399); Spurr's (*70*) polyvinyl alcohol-cadmium mixture (*n*, 1.467 to 1.6); and cellulose-caprate (*n*, 1.487), which sets rapidly, according to Lillie and Henson (*71*). Meyrowitz (*72*) has classified media of 1.74 and higher indices.

Motion Pictures

Phase cinephotomicrographs are reported by Pulvertaft (*73*) for medical applications; by Barski *et al.* (*74*) on cellular lesions produced by polio virus *in vitro*; by Gey *et al.* (*75*) on the plasma gell layer on normal and cancer cells; by Harman (*76*) on contracting skeletal muscle fibers; by Nakai (*77*) on tissue cultures of dorsal root ganglia; by Taylor and Gerstner (*78*) on the injurious effects of freezing tissue-culture cells; by Bessis (*79*) on immunohematology; by Pomerat *et al.* (*80*) on cell dynamics; by Pomerat and Lefeber (*81*) on the HeLa cell; by Blandau *et al.* (*82*) on movements of polymorphonuclear blood cells; and by Kramis and Hoyer (*83*) on changes in kidney cells from virus infection.

Microorganisms

Mason and Powelson (*84*) discovered more detail within bacteria immersed in

20- to 35-percent gelatin and propose this as a new technique (see also 3, 55, 63–66), and Müller (65) uses gelatin mounting medium for yeast. Phase microscopy gives more information and better diagnosis on stained flagellae than other methods, according to Burcik and Plankenhorn (85). Phase is used by Harold and Stanier (86) in the study of *Leucothrix* and *Thiothrix*. Beakley and Williams (87) describe spore formation in *Bacillus subtilis* and *Bacillus mycoides* and Keigler and Smith (88) found more detail with phase in the spores of *Bacillus cereus* after enzyme cytolysis. Pleomorphism of pleuropneumonia bacteria is investigated by von Prittwitz and Gaffron (89). Schnauder (90) describes the L-phase changes of *Salmonella* on liquid and semisolid media, and Bartman and Höpken (91) give similar information for pneumonia organisms after release by penicillin (92).

Phase microscopy is used by Ito (93) in the analysis of the life-history of *Bacillus aneurinolyticus*, a thiamine-decomposing bacterium isolated from human feces. Poetschke *et al.* (94) use phase microscopy to examine stained tuberculosis bacteria, and von Karger (95) found phase microscopy and Ziehl-Neelsen staining both less efficient than fluorescence microscopy for locating tuberculosis bacteria. Electron and phase microscopy are used by Gupta and Viswanathan (96) to elucidate the effects of chemicals on tubercle bacilli. Cortelyou *et al.* (97) describe the degenerative changes in the nuclei of *Escherichia coli* damaged by ultraviolet radiation.

Phase microscopy is used by Herzberg and Bommer (98) and by Stoeckenius (99) for the examination of vaccinia virus. Differentiation of virus inclusion bodies in insects described by Vago (100) is useful in diagnosis.

The nucleus of the polyploid yeast cell is examined by Mundkur (101) with phase and ultraviolet microscopy using frozen-dried material (see also 65). Moeschlin *et al.* (102) suggest that the plasma cells form the specific antibodies rather than the lymphocytes (see also 54).

Mites and Eels

Baker and Wharton's (103) monograph on the *Acarina* shows the phase microscope to be helpful in the study of mites. Using the phase microscope, Luft (104) finds an array of perpendicular rodlets resembling a brush border at the anterior and posterior surfaces of the electroplax of the electric eel.

Cytological Techniques

The phase microscope is used by Bloom *et al.* (105) and by Haselmann (106) in the evaluation of freeze-drying as a preparation method. Less structurally damaging changes seem to accompany this method than other methods of cell and tissue fixation. Motion pictures are used by Haselmann (107) for the study of fixation changes. Borysko (108) reports on the gross changes that occur in the preparation of cells for thin sectioning and methacrylate.

Mitochondria are examined by Harman (109), Kaltenbach and Harman (110), Bierling (111), and Elster and Hoppe (112). The Royal Microscopical Society published a symposium on the Golgi apparatus (113); although evidence from phase microscopy was helpful, the Golgi question remains unsolved. Sorokin (114) reports on filaments formed in the cytoplasm of lettuce epidermal cells under anaerobic conditions. Haselmann (115) continues on the analysis of collagen and de Brux and de Boistesselin (116) tell of the action of hormones on the collagen fibers. Palay and Palade (117) describe the organization of Nissl bodies and the fine structure of neurons, and Kotilainen and Wilska (118), on examining sciatic nerves with Anoptral phase contrast, cast some doubts on the reality of the nodes of Ranvier as they can be formed by manipulation. Nissl substance of chick embryo spinal ganglia is studied with phase and ultraviolet photography by Deitch and Murray (119).

As the means for disrupting cells for the isolation of parts improve, the phase microscope is used more often for checking the procedures—for example, Denues (120) uses phase to assess cell destruction in the isolation of chromosomes, and Mawson and Fischer (121) examined semen for aspermia before chemical analysis. When some of a homogenate preparation is put into 30-percent plasma albumin, according to Barer *et al.* (122), it is possible to distinguish living cells from nuclei because of the lower refractive index of cytoplasm, which may be present either with cell preparations or small lymphocytes. Brown (123) differentiates thymus nuclear fractions with phase microscopy, using an alkaline 0.25*M* sucrose solution and serum albumin.

General Histology

Phase microscopy in histology is reported by Linz (124) on the surface epithelium of liver; by Vago (125) on the structure of the guinea pig organ of Corti; by Pagani (126) and by Garzino (127) on fibers in the lens of the eye; by Bandmann and Kipfer (128) on nerve fibers; by Weddell *et al.* (129) on mammalian skin nerve endings; and by Batchelor and Pate (130) on the formation of elastic tissue in grafted aortic segments. Garzino (127) finds the phase microscope a useful link between observation with the biomicroscope and histology, since artifacts, owing to fixing and staining, are avoided.

Blood and Hematology

Franke's (131) well-illustrated little book includes brief descriptions and phase photomicrographs of many blood cells. Leukocyte locomotion is investigated by Kosenow (132) and leukocyte phagocytosis of *Streptococcus pyogenes* by Daglia (133). Bessis (134) is relating the structure of living blood cells seen with phase with that seen in the electron microscope. He reports that phase microscopy reveals detail better than stained preparations and that it aids in differentiating between monocytic leukemia and some monoblastic, or lymphocytic leukemias. Jeschal (135) finds little difference between leukemic cells and normal lymphocytes. The diagnostic differences seen with phase between atypical myeloblasts and lymphoblasts are described by Brausil (136), who believes also that the phase microscope shows details in living cells that cannot always be identified in fixed smears. Phase microscopy has advantages for blood counting in dermatology, according to Merklen and Cottenot (137). Ahlhorn (138) reports that phase is more precise than Fenio's dilution method for thrombocytes. Siering (139) uses phase for counting reticulocytes, and Berman *et al.* (140) use it for platelet counting in the hamster.

Unstained and supervitally stained living blood and bone marrow cells are described as seen with the phase microscope by Ackerman and Bellios (141). The affects of adrenalin and acetylcholine are examined on living leukocytes by Seitz (142). Although anti-Rh serum produces little specific hemolysis, it can be detected with the phase microscope, according to Ballowitz and Ballowitz (143). Klausewitz (144) reports cytodiagnostic studies of amphibian living blood and lymph cells, and Altman and Grundmann (145) describe nuclear structure of human leucocytes. P-amino salicylic acid cytochemistry of erythroblasts concerns Astaldi *et al.* (146), and Czerski and Pawelski (147) find that megaloblasts in Addisonian anemia show an increase in the chondrion neutral red vacuoles and sudanophilic bodies compared to normal erythroblasts. Man'i (148) examines hemolysis in a special chamber with a collodion membrane to separate the blood cells from a flowing dialyzing medium.

Embryology

The phase microscope, according to Dan (148), shows a filament produced by the acrosome of the starfish sperma-

tozoon, which forms the fertilization cone when in contact with the egg jelly. Cytoplasmic inclusions in spermatocytes and neurons of *Helix* are studied by Roque (*149*) with phase and interference microscopes. Oettlé (*150*) observes morphologic changes in human spermatozoa after ejaculation, and Shettles (*151*) reports that the fallopian tube mucosa secretes an enzyme that is believed to facilitate fertilization by denuding the human ovum. The form and migration of embryonic pigment cells in a special flat tissue culture cell are observed by Algard (*152*).

Medical Applications

General summaries of the advantages in phase microscopy in medicine include: Fritze and Strufe (*153*), Poetschke (*154*), Zinser (*155*) and Fröhlich (*156*). Yamaguchi (*157*) recommends the phase microscope for the examination of the cutting edges of scalpels. Suchowsky (*158*) states advantages of phase in the study of diabetes and kidney pathology. Bommer (*159*) uses phase to find *Trichromonas vaganalis,* and Silva-Insunza and Coutts (*160*) use it to find trypanosomes. Damage to mouse spleen from radiation is shown by Scherer and Wichmann (*161*). Hofmann (*162*) finds phase helpful in the histological evaluation of ascites cells with respect to cysteine protection against radiation.

Phase microscopy is becoming popular for the diagnosis of fresh, exfoliated vaginal cells. Maggipinto and Milani (*163*) can identify and classify the cells by phase as well as with the Papanicolaou staining. The acidophilic index is lost, but there is a gain in the morphologic detail seen. Runge *et al.* (*164*) use phase in the polyclinic, and Wied (*165*) urges that gynecologists look at fresh material immediately to determine the normals and send only the doubtful and abnormal preparations to the laboratory.

The general application of the phase microscope to the study of tumors is summarized by Albertini (*166*). His Tyrofusine AK method allows the study of fresh material and facilitates distinguishing between normal and tumor cells. Phase microscopy is also favored in tumor diagnosis in Albertini's (*167*) monograph. Bright-contrast phase is used by Gey *et al.* (*168*) in the study of normal and malignant cell tissue cultures. Hirsch and Hager (*169*) report that placing frozen sections of brain tissue in methylglycol provides suitable contrast so that brain tumors can easily be found with the phase microscope. Central nervous system tumors may be examined and graded during an operation on the brain as an aid to proper operative procedure (Calvo, *170*). Riegel (*171*) believes that the phase microscope is the optimal method for the diagnosis of bronchial carcinomas and provides a list of some 20 diagnostic criteria. Sternal marrow puctures may reveal tumors when they are examined with the phase microscope (Jeschal, *172*).

Industrial

The use of the phase microscope in metallography and in mineralogy is summarized by Mitsche (*173*), and Beyer (*174*) discusses vertical phase illumination of metal surfaces. Mott (*175*) observes lightly etched, single crystal cleavage faces of multiphase alloys. A phase telescope with a slit diffraction plate is used by Saunders and Smith (*176*) in the examination of flames. Claver and Merz (*177*) report the examination of styrene-rubber polyblends with phase, and Wigman *et al.* (*178*) have prepared standard photomicrographs of starch granules with the aid of high contrast, bright and dark-contrast phase objectives.

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Design Study of a Megacurie Source

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Now that power reactors are in the design and construction stage, it is interesting to note that many of these reactors can economically produce megacurie amounts of cobalt-60. To get a feeling for the economic feasibility of such a scheme, consider the case of a reactor generating 500 megawatts of heat power. Each watt corresponds roughly to 3×10^{10} fissions per second, and each fission will release about 2.5 neutrons, one of which must be spent in continuing the chain reaction while the others are absorbed in the system. Allowing one of these latter neutrons to be captured in cobalt-59 will produce 3×10^{10} atoms of cobalt-60 per second, per watt, or, utilizing only 2 percent of the power of the reactor to be used in producing cobalt-60, there will have been produced

$$(10 \times 10^{6}\ \mathrm{w})\left(3 \times 10^{10}\ \frac{\text{atoms Co}^{60}}{\text{sec}}\right) \cdot \left(\frac{0.693}{5.2\ \text{yr} \times 3.17 \times 10^{7}\ \frac{\text{sec}}{\text{yr}} \times 3.7 \times 10^{10}\ \frac{d}{\text{sec c}}}\right) \times 3.17 \times 10^{7}\ \frac{\text{sec}}{\text{yr}} = 1 \times 10^{6}\ \text{curie of cobalt 60/yr}$$

The cobalt can so be placed in the reactor that it will actually improve upon, rather than hinder, the efficiency of heat removal. For instance, cobalt can be used for the control rods of the reactor; it can also be used in flattening positions in the reactor; that is, it can be placed in such positions that the neutron flux distribution will be flattened, thus making the temperature distribution more uniform throughout the system and improving on the efficiency of heat removal; finally, cobalt can be put into peripheral positions in the reactor where it will have little effect on the flux distribution but will catch neutrons that ordinarily would have been lost to the thermal shield—thus the duty for the secondary cooling system on the thermal shield could be reduced and more heat could be directed to the power cycle.

At any rate, it is feasible in many power reactor designs to incorporate space for cobalt in such positions that the neutrons absorbed are essentially free, and the true costs involved are the cost of fabricating the cobalt pieces and the infrequent operational cost of removing

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the cobalt from the reactor and transferring it into shipping casks. Calculations have been made of the specific activity of cobalt-60 to be expected by irradiating cobalt-59 at various flux levels, and they are presented in Table 1.

Assume that there is available a 500-megawatt reactor where one can make use of 10 megawatts of the power generated, and that the 10 megawatts is available at an average depressed flux of 2×10^{13} neutrons per square centimeter, per second. In order to produce a megacurie of cobalt-60 in 1 year, having a specific activity of approximately 22 curies per gram, one will have to insert in the reactor $10^6/22 = 4.55 \times 10^4$ grams of cobalt-59. Although the particular geometry of the individual pieces of cobalt may depend on the ultimate use of the radiation sources, for the purposes of this paper assume that the cobalt is fabricated into rectangular slabs 1 inch wide by 0.160 inch thick by 10 inches long, these dimensions including 0.030 inch of stainless steel cladding. Each element will contain 136 grams of cobalt and will have a total weight of 221 grams. Thus, a total of 334 of these elements will be required, each of which will contain approximately 3000 curies.

Radiation Levels

In use as a radiation source, these elements can be assembled in various ways. Assuming that a flat-plate geometry is desired, the radiation level to be expected immediately in front of the array (1 centimeter away in air) can be calculated by assuming that at this distance the source is essentially an infinite slab source of finite thickness. The radiation intensity, I, in roentgens per hour, at such a point is given by the expression:

$$I = \frac{1.52 \times 10^8 S_v \mu}{\nu} [1 - F_1(\nu h)] \quad (1)$$

where S_v is the specific activity in curies per cubic inch, μ is the absorption coefficient of the gamma rays in air, ν is the absorption coefficient of the source material, h is the thickness of the source, and $F_1(\nu h)$ is defined as

$$F_1(\nu h) = \int_1^\infty x^2 e^{-\nu x} dx \quad (2)$$

the so-called Gold integral. Taking the values $S_v = 3210$ curies per cubic inch (averaged over entire array), $\mu = 1.74 \times 10^{-4}$ per inch, and $\nu = 1.19$ per inch (an average for the relative amounts of stainless steel and cobalt), Eq. 1 reduces to

$$I = 7.18 \times 10^7 [1 - F_1(\nu h)] \quad (3)$$

The results of applying Eq. 3 to a range of thicknesses of the source are shown graphically in Fig. 1, where the

Table 1. Specific activity of cobalt-60 obtained by irradiating cobalt-59.

Neutron flux* (n/cm², sec)	Atom % of Co^{60} after 1 yr	Curies of Co^{60} per gram after 1 yr
10^{12}	0.100	1.17
10^{13}	0.990	11.6
10^{14}	9.52	111

* The flux used here is not the undepressed flux but the flux that the cobalt actually sees.

radiation intensity at 1 centimeter in air from the center of a flat plate made by assembling the 334 elements into a roughly square sheet is plotted against the thickness. The radiation level near the surface of the most extended array ($h = 0.160$ inch) is 2.97×10^7 roentgens per hour and approaches an asymptotic value of 7.18×10^7 roentgens per hour as the array is condensed to a rough cube many elements thick.

Shipping-Container Problem

Plotted in the same figure are the tons of lead shield necessary to reduce the radiation level to 100 milliroentgens per hour (or lower at the ends) on the outer surface of the container. This value approaches an asymptotic value of 6.5 tons. Figure 2 is a plan view of the shielded array.

It would appear then that it might be feasible to design a shipping container to transport safely and store a megacurie of cobalt-60, if the only concern were safeguarding against the radiation emitted by the source. However, this quantity of cobalt-60 would generate 15 kilowatts of power, all of which would be dissipated as heat within the source itself and the shield material. Thus, serious thought must be given to the proper design of a container for a megacurie of activity that will properly shield against radiation and, at the same time, provide for the safe dissipation of the heat energy thus generated.

The first question to be resolved is whether or not multiple shipments of quantities of less than 1 million curies are to be considered. By reducing the curies per shipment sufficiently, one may effectively eliminate one of the main design problems—the removal of heat generated by the source. However, the weight of shielding required does not decrease in proportion. As a means of illustration, a 3000-curie source in the form of one of the afore-mentioned metal strips would probably require about 1.5 tons of shielding, but one could neglect the heat-removal problem.

It is shown in subsequent paragraphs that a suitable facility for transporting 1 million curies can be designed, which would weigh less than 15 tons, but the heat-removal problem must be given careful consideration. On the basis of

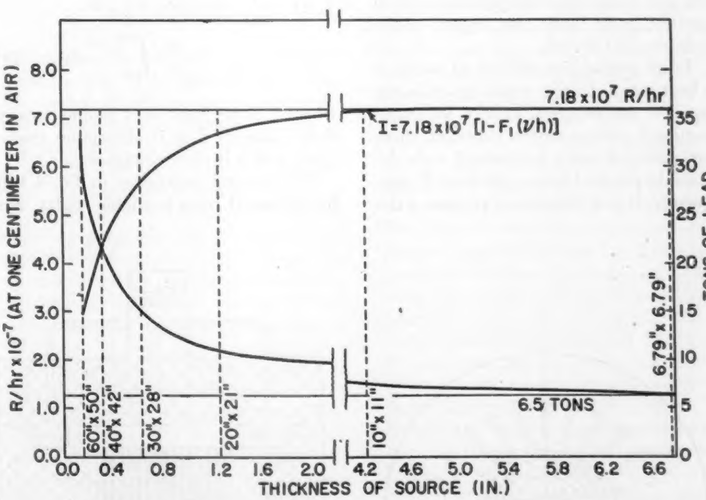

Fig. 1. Results of applying radiation intensity to a range of thicknesses of the source.

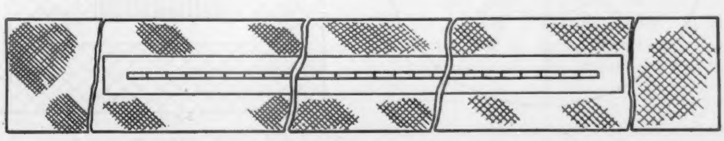

Fig. 2. Array for shielding and intensity calculations.

equal weight, 48 shipments each, consisting of seven of the 3000 curie sources, would be required for the transportation of 1 million curies as compared with one shipment with the single facility. Obviously, there are intermediate cases that compare much more favorably than the illustration given here, but this illustration does lend justification to considering the transportation in a single shipment, which is done in the discussion to follow. It might be added that a facility for transporting 0.5 million curies, rather than 1 million, would not differ significantly from the one to be described below.

Before proceeding any further, it might be well to state qualitatively some of the requirements that should be met by a properly designed facility. (i) The facility must be properly shielded. (ii) The temperature in the lead shield must always be below the melting point of lead, since any small crack developing in the container during shipment might result in complete loss of shield if the lead were in a molten state. (iii) The use of power-driven auxiliary equipment should be avoided, if possible, since loss of power might lead to intolerable conditions. (iv) It should be borne in mind that the facility must be loaded and unloaded and, hence, should be designed to permit such operation without leading to intolerable conditions. (v) In general, the temperatures throughout the facility should be as low as possible to reduce thermal stresses in the shield container and also in the cobalt strips themselves to prevent, in the latter case, rupture of the stainless steel sheath.

In all probability, the use of water as a heat-removal agent would result in the smallest size practical facility for transporting 1 million curies. However, there are potential hazards involved with the possible physical loss of coolant. Consequently, it was decided to attempt a design that would use air as a coolant and heat-transfer media.

Table 2. Temperature values for a megacurie source.

Air circulation rate (lb/hr)	Assumed emissivity of stainless steel surface	t_1* (°F)	t_2* (°F)	t_3* (°F)	t_4* (°F)	Remarks
0	1	340	444	510		No air circulation
0	0.5	410	516	590		No air circulation
162	0.5	317	350	440	353	Natural circulation; no stack
400	0.5	273	300	350	308	Natural circulation; 6.4 ft. stack
1000	0.5	185	200	245	210	Forced convection

* It will be noted that in most cases these are maximum temperatures for the general location.

All the heat generated in the cobalt must be transferred across an air gap which offers a large resistance to transfer and thereby results in a very large temperature difference. It is readily apparent that this could be avoided if the gamma radiation were absorbed in shield material rather than in the cobalt. This can be accomplished by dividing the entire cobalt mass into smaller masses, each surrounded by shield material. In order to determine the extent of subdivision necessary, one requires information on the fraction of gamma energy that is absorbed in various geometric shapes. Of particular interest in this design is the fraction absorbed in flat strips. For an infinite flat plate of thickness "b," the following equation may be derived:

$$f_a = 1 - \frac{1}{2\mu b}(1 - e^{-\mu b}) - \frac{1}{2}e^{-\mu b} + \frac{\mu b}{2}\int_{\mu b}^{\infty}\frac{e^{-x}}{x}\,dx \qquad (4)$$

where f_a is the fraction of gamma energy that is absorbed, μ is absorption coefficient, and b is plate thickness.

The integral expression in Eq. 4 can be evaluated from available tables. For an infinite plate of thickness corresponding to one of the afore-mentioned cobalt strips, the fraction of gamma energy absorbed would be 0.30. For an actual finite strip of the dimensions given here, the value would be less than this. It has been estimated that in such a strip the fraction of the total energy absorbed (both β and γ) would be about 0.33, assuming that the beta energy (amounting to 11.5 percent) is totally absorbed by the cobalt.

It is obvious from this calculation that, if most of the energy is to be absorbed in the shield material, then individual strips must be used, each surrounded by shield material. Thus, a practical facility would consist of a shield block containing a central core consisting of a large number of slots, each containing one or more cobalt strips. This is surrounded by further shielding to reduce the intensity of radiation to a tolerable value at the surface. One proposed design is shown in Fig. 3.

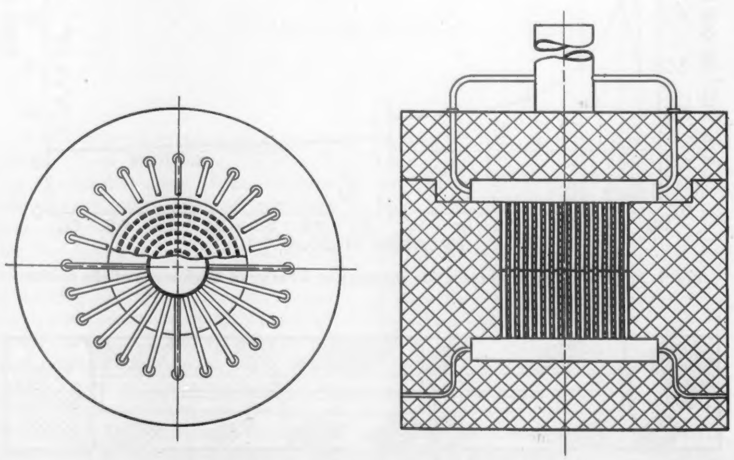

Fig. 3. Shielded container for megacurie source.

The spacing between slots must be given careful consideration. If the slots are too close, then the contribution of nearby strips to the absorption in any one particular strip will be excessive, and the figure of 33 percent given in a foregoing paragraph would be raised appreciably. On the other hand, too great a spacing would add unnecessarily to the size and weight of the facility. An arrangement allowing 0.5 inch of shielding material between strips was selected after consideration had been given to the afore-mentioned factors. Another result of subdividing the total mass of cobalt is the increase in area available for heat transfer. Rectangular slots were selected in preference to circular ones, mainly because this particular geometry allows more shield material in the central core.

To increase the efficiency of the facility with regard to the removal of heat, the facility has been designed to permit natural circulation of air through the slots. This has been done by means of a large number of connecting tubes, as is shown in Fig. 3. The number and size of tubes is governed by two factors: (i) the pressure drop through the facility and (ii) the level of radiation scattered through the tubes. It will be observed that none of the cobalt strips actually sees out the

tubes, and hence radiation reaching the outside must arise from multiple scattering processes. This consideration requires that the tubes be small.

The fluid-flow relationships involved either require relatively few large tubes or a large number of small tubes. With respect to the fluid-flow relationship, the criterion used was to make the largest individual pressure drop be that associated with the slots, since their size, as described here, is governed by other factors and not easily subject to change. As a result, many small tubes are used. The natural circulation can be improved by adding a stack to the facility, as is shown.

The over-all dimensions of such a proposed facility would be about 4 feet in diameter by 4 feet in height, with a 6-foot stack having an internal diameter of about 10 inches. The weight of such a unit would be about 13.5 tons. The inner cylindrical core (containing the rectangular slots) would be about 2 feet in diameter by 2 feet in height. Each slot would contain two cobalt strips arranged vertically, one above the other. Since 334 strips are required to constitute a megacurie, 167 slots would be required, and these would be arranged on concentric circles spaced 1½ inches apart. Each rod in a given circle would also be about 1.5 inches apart, from center to center. Since each slot is 1 inch by 0.5 inch, the thickness of lead between slots (and hence between cobalt strips) would be 1 inch in a radial direction and 0.5 inch along the circumference of the circle. The air chambers above and below the central core would be 4 inches in height, and there would be 100 1-inch tubes in the top and bottom sections to permit circulation of air.

The temperatures of interest in such a facility are those at the outer surface, in the central core, and in the individual cobalt strips. Since these temperatures are dependent on position, the values given in Table 2 refer to specific locations as follows: t_1 is the temperature of the outer surface at a point midway between top and bottom; t_2 is the temperature at the center of the core; t_3 is the temperature at the center of a cobalt strip; and t_4 is the temperature of the air in the tubes leaving the facility. The calculations that led to the results given here involved many assumptions and approximations, which are too numerous and too involved to discuss in this paper.

Bendix Time-of-Flight Mass Spectrometer

W. C. Wiley

The combination of high resolution with the speed of response and geometric simplicity of time-of-flight mass spectrometers makes possible the application of mass spectrometry to a number of analysis and research problems which heretofore have not been well suited to this technique. The development of the Bendix spectrometer began with the invention of a new ion gun (*1*) which was capable of providing very high resolving power when used in a time-of-flight mass spectrometer. Further development work was encouraged by the inherent versatility of the instrument both in its operation and in its design. Several models have now been designed and built on special order to satisfy a number of different applications. Following a description of the spectrometer's operation and a summary of its characteristics, some of these applications are discussed.

Operation

Several classes of mass spectrometers are commonly referred to as time-of-flight instruments. The Bendix spectrometer belongs to the class which probably represents the most straightforward application of time of flight to mass spectrometry and, in its simplest form, consists merely of an ion source and an ion collector situated at opposite ends of an evacuated tube, as is shown in Fig. 1.

Ions are first formed, usually by electron bombardment, between the two electrodes of the ion source. By applying a voltage pulse between these electrodes, the ion bunch can be ejected through an opening or grid in one of the electrodes. Because the ions, as a result of the accelerating field, reach a velocity that is a function of their mass to charge ratio, the original bunch of ions separates as it passes through the field-free region between the source and the detector into several bunches, each containing ions of a specific mass to charge ratio. Hence, the light ions will reach the ion detector first, followed in succession by the heavier ions.

One of the many methods in which the Bendix spectrometer can be operated is described in more detail with the aid of Fig. 2. The first event in the creation of a single mass spectrum, many thousands of which may be formed every second, is the establishment of the electron beam in the temporarily field-free ionizing region. This beam, which usually lasts a fraction of a microsecond, is produced when electrons are drawn off a hot filament by a voltage pulse applied to the adjacent electrode. After this beam is turned off, grid 1 is pulsed to eject the resulting ion bunch into the accelerating region. The direct-current source potentials are arranged so that the ions receive their major acceleration as they pass through this area on their way to the field-free separating region or drift space.

If the ions before pulsing were at rest and all in a plane parallel to the electrodes, almost any method of ejecting them from the source would provide infinite mass resolution, regardless of the total length of the flight path. The resolving power of the instrument is, therefore, a measure of the ability of the source to deliver the ions of one mass to charge ratio to the detector in a sharp pulse, even though the ions will inevitably vary in initial position and velocity. The effect of variations in the ions' initial position can be reduced by taking advantage of the fact that those ions farther away from grid 1 fall through a larger potential during the ion-ejection period than do those nearer this grid. The trailing ions will, therefore, acquire a greater velocity and will eventually overtake those in front. A proper adjustment of the fields in the ionizing and accelerating regions, usually made by varying the height of the ion-ejecting pulse applied to grid 1, causes the "crossover point" for all ion peaks to occur as they pass through grid 3 into the ion detector. The deleterious effect of initial ion velocities on the resolution of a time-of-flight spectrometer can be reduced in two ways: (i) the final velocity of the ions can be

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made large relative to their initial velocities; (ii) the time during which the ions are traveling with their final velocity can be made large compared with the total time of flight. The latter method has the effect of increasing the average velocity of the ions during their total flight time relative to their initial velocities. The high resolution produced by the Bendix spectrometer compared with other time-of-flight instruments is in large measure due to its ability to give the ions a high average velocity without using prohibitively high voltages or requiring a speed of response in the ion detector and output system beyond present electronic art.

A mathematical treatment of the focusing action of this source has appeared in a previous article (*2*). The time of flight for an ion of mass M and charge q is $T = \lambda(M/q)^{1/2}$, where λ is a function of dimensions and voltages. A representative value for the flight time of a singly charged nitrogen ion ($M = 28$ atomic mass units) is 5 microseconds, and under usual conditions the time width of the nitrogen pulse at half height is about 0.015 microsecond.

A magnetic electron multiplier is used to detect and amplify the ion bunches, or peaks. The ions pass through grid 3 into the electron multiplier, strike the first multiplying plate or dynode, and produce secondary electrons. These electrons follow cycloidal paths under the influence of the mutually perpendicular electric and magnetic fields in the multiplier. After suitable multiplication, the resulting output signal can be displayed on an oscilloscope synchronized with the ion-accelerating pulse.

Characteristics

In large measure, the inherent stability and ruggedness of the Bendix spectrometer result from the simplicity of the mechanical construction. Since the resolution depends on temporal, rather than geometric factors, no accurate alignment or stringent geometric conditions are required. The size and shape of the evacuated volume is not restricted by the presence of a magnet, so that the effects of stray fields, arising from contaminated surfaces, can be minimized. This consideration, coupled with the fact that the performance of the instrument is dependent on only a small number of electrodes, permits the physical design to be quite flexible. Thus the problem of modifying the device for specific purposes is greatly simplified.

The resolution of the Bendix spectrometer varies with several parameters, such as flight time, flight-path length, and ion-source dimensions. As the in-

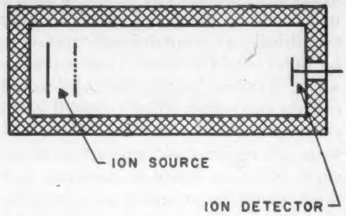

Fig. 1. Basic geometry of the Bendix spectrometer.

strument parameters are varied to improve resolution, the sensitivity drops. The best resolution achieved to date is illustrated by the oscillogram shown in Fig. 3, while the compromise between resolution and sensitivity chosen for recent models gives the "normal" resolution shown in Figs. 4 and 5. Careful oscilloscope measurements have been made of this normal resolution at many masses up through xenon. Direct measurement on higher masses have not yet been made, but extrapolation of the data taken in this lower mass range shows that mass 400 atomic mass units should contribute about 1 percent of its height to adjacent peaks and mass 600 atomic mass units has a width at half-height equal to the time separation between the centers of masses 600 and 601.

An important characteristic of this instrument is the speed with which an analysis can be made. If one takes pictures of an oscilloscope screen, it is possible to get a complete analysis recorded in a few microseconds. It should be noted that, although the mass spectrum might take 10 to 20 microseconds to be detected, the ions in this mass spectrum were all formed during a fraction of a microsecond in the ion source; and thus the spectrum represents the average composition of the sample during a period no longer than a fraction of a microsecond. As in all mass spectrometers, the sensitivity depends on the resolution. Sensitivities on the order of 1 part in a million are theoretically possible in the low mass range.

There are several ways in which the mass spectra can be recorded. The simplest is the oscilloscope display mentioned previously, which exhibits the maximum resolution of the instrument and preserves the inherent speed of analysis. Some applications, however, require greater accuracy and sensitivity than those obtainable through oscilloscope presentation. For these, the magnetic electron multiplier has been further developed to provide three separate anodes. One of these anodes is usually connected to the oscilloscope. The other two can be activated electronically (gated) so that any portion of the mass spectrum can be directed onto each of these anodes, the remainder of the spectrum going to the oscilloscope anode. The two gated anodes are usually connected to an integrating direct-current amplifier which produces a voltage proportional to the average area under that part of the mass spectrum selected. The ratio of the two voltages obtained in this way can then be obtained and recorded if desired. Ratio recording has several advantages stemming from the fact that any variable in the machine which changes the size of all peaks proportionally will have no effect on ratios. Thus, changes in the electron-beam intensity, the gas flow into the instrument, or the amplification of the multiplier do not affect the analysis and, consequently, do not require precise regulation. Applications utilizing this ratio output are described later.

A modification of this ratio-recording principle involves the use of pulse-counting techniques. Some ion peaks are so small that an average of less than 1 ion appears each cycle. The ratio of two such peaks can be taken by counting the pulses that occur during the time interval belonging to each peak and comparing the two counts periodically. The noise pulses produced by the multiplier are equivalent to an ion pulse containing about 6×10^{-6} ions, so that noise pulses do not impose a serious restriction on measuring small peaks by this method.

Applications

Probably the most obvious application is the analysis of very fast chemical reactions, especially analyses in which one is attempting to detect radicals with half-lives in the microsecond region and which must be detected before they have suffered any wall collisions. One of the instruments of this type is designed to produce a spectrum every 50 microseconds which is photographed by a high-speed camera. The ionizing region and the reaction chamber are separated by only a thin wall with a small pinhole through it,

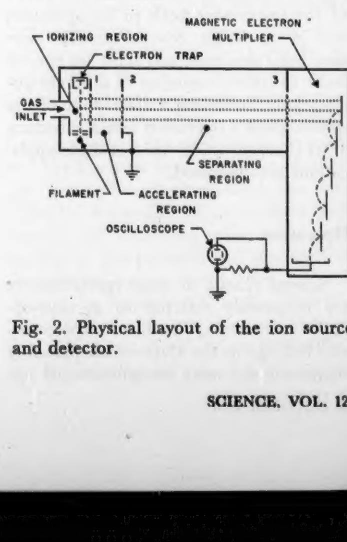

Fig. 2. Physical layout of the ion source and detector.

assuring the smallest possible path length for the radicals before ionization. The electron beam is directed to graze the inner side of this pinhole so that the gas is being ionized at the point where its pressure is the greatest.

Perhaps the biggest problem in this type of analysis is reducing the background to a sufficiently small value. Background gas in this case includes not only products from the diffusion pump and gases originating in the walls of the vessel but also any molecules that have gone through the pinhole and have rebounded against a surface at least once. Thus, it is important to keep any surfaces in front of the pinhole to a minimum, so that a particle after rebounding will have a much greater chance of being captured by the pumping system than of returning to the ionizing region. This is accomplished by using accelerating grids with very high transmission factors, providing a large evacuated volume beyond the ion source, utilizing large diffusion pumps, and preventing ions that are formed by the electron beam in a region other than that directly in front of the pinhole from ever reaching the ion collector.

A promising approach to the problem of producing chemicals more efficiently, which has been receiving attention recently, is the utilization of fast reactions nearing the speed and violence present in a ram jet engine (*3*). Some fast reactions are already utilized by the chemical industry; for instance, ethylene is made with high efficiency from propane gas by simply passing the propane through a hot tube. However, the wide application of these fast reactions is being limited by the difficulty of determining the complete chemical processes involved, especially the identity of the many intermediate products, some of which have more value than do the end-products. The ability of the Bendix spectrometer to help solve some of the formidable instrumentation problems should materially contribute to the development of this rapidly growing field.

There is another class of problems suitable for mass spectrometers which utilize only an oscilloscope as an output system but do not require the extreme speeds necessary in very fast reaction work. One of the most interesting applications is in the identification of the separated components emerging from a vapor-phase chromatographer. The common method for identifying each component is to measure the time lapse between the introduction of the mixture and the emergence of the separated component from the chromatography column as indicated by a thermal conductivity gage. If the same column has been previously calibrated with this same component under identical column temperature, carrier gas pressure, and carrier gas flow rate conditions, this emergence time can be used for identification. For general analysis applications, however, such a limitation to one set of operating conditions is a definite disadvantage, since the full resolution possible with chromatography depends on the utilization of many different column temperatures, flow rates, and especially column materials. Switching from one set of operating conditions to another not only varies the emergence times of separated compounds but, in some cases, the order of emergence as well. The mass spectrometer has been used to identify the emergent compounds, but heretofore this has required tedious collection of each component in a separate sample bottle and subsequent admission of each sample in turn to the spectrometer.

Using the Bendix spectrometer, the identification of the emerging components can be made simply by allowing a portion of the effluent gas to pass into the spectrometer. As each unknown emerges, its unique spectrum will rise and fall on the oscilloscope screen, affording positive identification in most cases. Photographs of the mass spectra can be taken if a permanent record is desired, and the relative abundance of the components can be determined by monitoring multiplier output current or utilizing a conductivity cell in the conventional manner.

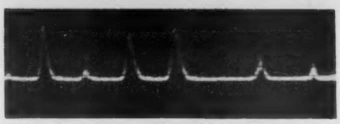

Fig. 3. Oscillogram of the mass spectrum of some xenon isotopes. The masses are, from left to right, 128, 129, 130, 131, 132, 134, and 136 amu.

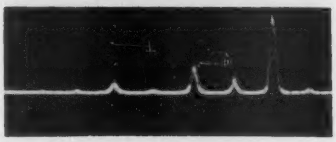

Fig. 4. Oscillogram of a section of the n-butane mass spectrum. From left to right, the masses are 39, 40, 41, 42, 43, and 44 amu.

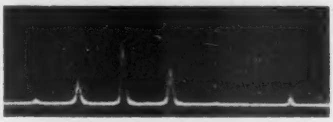

Fig. 5. Oscillogram of a portion of the spectrum produced with a mixture of air and n-butane. The masses, from left to right, are 26, 27, 28, 29, 30, and 32 amu.

Because of its inherent characteristics, the ratio system described here promises to create important applications for this instrument in the process monitoring and process control fields. The relative independence of the ratio output with source pressure, source temperature, electron-beam current, and multiplier gain leads to a relaxation of regulation and calibration requirements, and the simplicity and ruggedness of the design facilitates adaptation to industrial-plan operation. Another advantage derived from the independence of the ratio output on source pressure is the feasibility of automatic calibration by rapid sample stream switching. Consider a ratio system that switches the sample stream between a standard and an unknown or process stream many times a second and then detects the ratio difference existing between the standard and the unknown with a null detector tuned to the frequency of the sample switcher. It would be difficult in such a system to hold the source pressure constant, but this is not necessary with ratio operation, since both peaks of the ratio are affected proportionately by source pressure changes. Sample switching coupled with the null detection of a ratio greatly reduces dependence on operating variables and produces a continuously calibrated signal.

In some pilot-plant operations, the ratio output could be used to optimize more quickly the process under investigation. In those stages of the process which could be optimized by maximizing or minimizing a ratio of two peaks or two sections of the spectrum, much time could be saved by inserting the sample system of the spectrometer directly into the process stream and changing the plant-operating variables while watching the ratio. The oscilloscope spectrum could also contribute valuable information during this procedure.

Applications in the chemical laboratory also exist for the Bendix spectrometer. In many cases, the samples produced in laboratories are analyzed by a separate mass-spectrometer group, often resulting in serious delays. The simplicity and low cost of this instrument when it is equipped with only an oscilloscope output make it practical for a chemist to use it in his own laboratory as a versatile, fast-responding tool to aid him in simple analyses and the monitoring of chemical reactions. A number of accessories can be used with this instrument to increase its versatility, such as standard sample systems, independently timed oscilloscope sweeps on alternate cycles so that any two mass peaks can be brought into coincidence on the screen for direct

comparison, simple pulse-counting systems that measure peaks containing less than 1 ion per spectrum which allow one to utilize the full sensitivity range of the instrument, and simple gating systems which allow conventional recording of mass spectra.

An experiment recently performed concerning the detection of metallic ions may suggest other applications for the instrument. It was desired to check the dependence of resolution on initial energies considerably higher than those usually encountered, and for this purpose a beam of metallic molecules, thermally emitted from a hot source, was allowed to pass through the ionizing region at right angles to the electron beam and parallel to the source electrodes. As was expected, the resolution was unaffected by this transverse velocity. In general the resolution and intensity obtained with metallic vapors have proved to be very similar to those that would be obtained with gases at the same molecular density. It was possible, however, to detect a shift in the direction of travel of the metallic ion beam as compared with the background ions, the metallic ions being displaced at the collector in the direction of their high initial velocities. This fact can be turned to advantage by aiming the metallic ions directly at the collector, causing the majority of the background ions to be lost to one side. With aluminum vapor, an improvement of a factor of 10 for the sensitivity of the metallic vapor as compared with the background gas was obtained in this way.

Another application in the experimental field is to measure the lifetime of different types of ions by varying the time between the shutoff of the ionizing electron beam and the beginning of the ion-acceleration pulse. With most source geometries it is possible to have a lag between ion formation and ejection from the source of about 5 to 10 microseconds.

Conclusions

Many of the applications of the Bendix Time-of-Flight Mass Spectrometer make use of the instrument's high resolution, speed of response, and simplicity. Among these are studies of fast reactions, the monitoring of chromatography columns, fast, moderately accurate chemical analyses, the optimizing of pilot-plant operations, the detection of metallic vapors, and studies of ion lifetimes.

Further experience is expected to uncover other applications to the problems of science and industry where the unique characteristics of this instrument can be of service.

References and Notes

1. U.S. patent 2,685,035.
2. W. C. Wiley and I. H. McLaren, *Rev. Sci. Instr.* **26**, 1150 (1955).
3. L. P. Lessing, *Sci. Am.* **188**, No. 5, 29 (May 1953).

News of Science

Phosphagen of Tunicates

It has been established that invertebrates and vertebrates differ with respect to their phosphagens. Thus, phosphoarginine is characteristic of invertebrates and phosphocreatine of vertebrates.

The invertebrates, however, exhibit some variability [Baldwin, *Dynamic Aspects of Biochemistry* (Cambridge Univ. Press, ed. 2, 1952)]. Although most of the five extant classes of Echinodermata possess nonprotein arginine and so follow the general invertebrate pattern, the Ophiuroidea contain creatine and the Echinoidea both arginine and creatine. A few invertebrates are devoid of both phosphoarginine and phosphocreatine but possess one or the other (gephyreans, some polychaete annelids) or both (some polychaetes) of two recently discovered phosphagens that contain neither arginine nor creatine. On the other hand, phosphocreatine is the only phosphagen present in vertebrates.

The protochordates (Hemichordata, Urochordata, Cephalochordata), although they are grouped together with the vertebrates to form a single phylum, the Chordata, are recognized as being morphologically intermediate between invertebrates and vertebrates. Their biochemical affinities, and hence their phosphagens, are therefore of considerable interest (see Baldwin, 1952). Only phosphocreatine is present in Cephalochordata (lancelets), which thus most closely resemble vertebrates, as they do in their morphology. On the other hand, the Hemichordata (sea acorns), which exhibit the greatest structural affinities with invertebrates, appropriately possess both the arginine and creatine compounds. Since 1932, the Urochordata (tunicates or sea squirts) have been regarded as quite anomalous among chordates in this respect, for the studies of both Flössner and Needham *et al.* have indicated the presence of phosphoarginine, but not of phosphocreatine, in these animals. Hence, in this respect, the tunicates have been thought to resemble the invertebrates.

Morrison, Griffiths, and Ennor have recently reported a study of two species of tunicates, *Pyura stolonifera* and *P.* sp. [*Nature*, **178**, 359 (18 Aug. 1956)] in which they found no traces of arginine, phosphoarginine, or arginine phosphokinase. However, the presence of creatine, phosphocreatine, and an enzyme possessing creatine phosphokinase activity was established. The authors note that, although it may not be permissible to conclude that tunicates as a class possess phosphocreatine, their findings on *Pyura* do relieve these animals of their anomalous position and provide biochemical support for their accepted classification among the chordates.

It would seem of interest to investigate the phosphagens of other species of tunicates, including those already studied by earlier workers. It may well be that Flössner, Needham *et al.*, and Morrison *et al.* are all correct; if so, the tunicates possess more than one type of phosphagen, which varies with the species, sometimes being phosphoarginine, as in invertebrates, sometimes phosphocreatine, as in vertebrates and lancelets, and sometimes, perhaps, both of these compounds, as in hemichordates. This would befit the accepted phylogenetic position of the Urochordata.—W. L. S., Jr..

French Atomic Power

France became the first country on the West European continent to produce electricity by atomic means on 28 Sept. On that date the atomic center at Marcoule, on the Rhone River north of Avignon, began to produce sufficient heat to make vapor, which in turn started the operation of specially constructed turbines.

The pile, the first of three that will be built at Marcoule, began operating in

January, and its power has been progressively increased since then. It is now producing 30,000 kilowatts of heat energy, three-fourths of the total capacity that is expected to be reached in a few weeks. When the maximum power of 40,000 kilowatts of heat energy is reached, approximately 5000 kilowatts of electricity will be produced. However, between 7000 and 8000 kilowatts are needed to run the blowers that cool the pile.

The Marcoule center is primarily a producer of plutonium. Electricity on a commercial basis will not be produced in France before 1959, when a plant in the Loire Valley is constructed. It will have a capacity of 300,000 kilowatts.

Hyksos Tomb

Hebrew University archeologists working in the area of the biblical town of Tel Hazor, in northern Galilee, have reported the discovery of what seems to be an unopened royal tomb of the Hyksos period. Yigal Yadin, former chief of staff of the Israeli Army, and Jean Perrot have found a circular staircase leading into a rock tunnel that is behind an arch such as is found only in royal tombs. The tunnel is still blocked by tons of debris.

The Hyksos were the earliest invaders of Egypt, conquering it about 1685 B.C., according to Josephus, Jewish historian at the start of the Christian Era. He also identified them as Israelites. Historical records of the Hyksos period are rare, and few archeological traces of it have been found.

Salk and Sabin Vaccines

The National Foundation for Infantile Paralysis has announced that recent work reported by Albert B. Sabin of the University of Cincinnati in the development of a live-virus vaccine against paralytic poliomyelitis does not affect the current use of the Salk vaccine. The foundation has supported the work of both Sabin and Salk. Sabin's experimental oral vaccine contains attenuated strains of live virus, while the Salk killed-virus vaccine is injected in a series of three shots spaced over a period of 8 months.

In a statement to the press, Thomas M. Rivers, medical director of the foundation, said: "The Salk vaccine is safe, effective and available today. The Sabin vaccine still is in an experimental stage. As Dr. Sabin himself has pointed out, it is impossible to estimate how long it might take to test and prove the effectiveness of the new vaccine in human beings. But we know that the Salk vaccine has been 75 to 80 per cent effective. It would be tragic if parents, misled by the report of a possible future vaccine, delayed the use of the vaccine which now is available for protection against paralytic polio." Rivers also commented that the foundation has received no request from Sabin for mass testing of his new product.

Engineering Graduates Here and Abroad

Comparative data for the graduating classes of engineers for 1954 in Great Britain, the United States, and the U.S.S.R. are as follows: Great Britain graduated 57 engineers per million of population; the United States graduated 136 engineers per million of population; and the U.S.S.R. graduated 280 engineers per million of population.

The available data for the U.S.S.R. show that the Soviet Union is graduating an additional 326 lower-grade engineers per million of population. Although the population of the U.S.S.R. is about one-third greater than that of the United States, she is graduating more than twice as many engineers as the United States.

Doctor Draft

The special draft law passed in 1950 that permitted the induction of physicians and dentists up to the age of 50 will expire next June, and the Department of Defense has let it be known that next year the military will rely instead on the regular draft to get its medical staff. More than 30,000 physicians, dentists, and veterinarians have been called to duty under the provisions of the law, which was extended in 1951 and 1953 and again in 1955.

The American Medical Association and the American Dental Association have long protested that the law was discriminatory. Under the regular draft, men under 35 may be inducted. Only about 200 more doctors are expected to be called before the law expires.

Erythromycin Molecule

The complete molecular structure of erythromycin has been determined after 4 years of research at Eli Lilly and Company, Indianapolis, Ind. The team of organic chemists who participated in the work included Edwin H. Flynn, Koert Gerzon, Max V. Sigal, Jr., Paul F. Wiley, Ollidene Weaver, Rosemarie Monahan, and U. Carol Quarck (who is now at the Organic Chemistry Institute, Technical University, Berlin-Charlottenburg).

Erythromycin, which is produced by the soil mold *Streptomyces erythreus,* is widely used by the medical profession, particularly against common bacterial infections. It was discovered in the Lilly laboratories in 1951 and given the trade mark Ilotycin (Erythromycin, Lilly). The determination of the molecular formula will aid research to develop new forms of the antibiotic and to study its metabolism and physiological action.

The formula is $C_{37}H_{67}NO_{13}$. The molecule consists of a large lactone ring, called erythronolide, to which are attached two unusual sugars, desosamine and cladinose. The desosamine structure was worked out by chemists of another laboratory after the Lilly group had isolated, characterized, and named it.

Part of the structure work on erythromycin has been detailed in the *Journal of the American Chemical Society* [**78**, 388, 808 (1956)], and the final reports are to appear in that publication in the near future.

Report of the Pentagon's New Industrial Security System

The Department of Defense has issued an unusual 200-page report on the functioning of its arms plant security system. This *First Annual Report* of the Pentagon's Industrial Personnel Security Review Program, subtitled "Security at work" has an illustrated cover, charts, and a clearly written text.

Breaking precedent, the report cites 30 case-histories to illustrate how the security system works. Although most of the cases seem to be clear-cut ones in which security clearance should have been withheld, one case-history disclosed that a "research scientist of national stature" had been finally granted clearance in the face of charges that his mother was a known Communist and his father a supporter of Communist-front organizations, and that he himself had gone to Russia to do research work in the 1930's, had read the *Daily Worker,* and had shown a "sympathetic interest" in Communism.

The report stresses that the Government has a duty to release as much information as possible regarding security cases, to avoid the "confusion and misunderstanding" that has resulted in the past because of partial disclosures. It also defends the limited use of "faceless informers." In general, the report presented the following information.

Under the new centralized control system and improved local screening procedures, the number of disputed security cases arising among the some 2 million employees of defense plants has been sharply reduced since April 1955 when the clearance system was revised.

For fewer clearance denials are forwarded by local agencies to the Pentagon, and of these, clearance is being granted in a higher percentage of cases. During the first 14 months of the present system,

418 cases were submitted for Pentagon screening; in 250 cases lower authorities were overruled and clearances were granted. This is a 60-percent approval rate, compared with 37 percent during the previous 2 years, when only 622 of 1672 appeals for clearance were granted. In addition, a much larger percentage of cases was settled before the people involved had to be notified and hearings held, with the consequent harm done to those concerned.

In a news conference about the report, Jerome D. Fenton, director of the Defense Department Office of Personnel Security Personnel Policy, stated that of all the cases considered, about half involved loyalty questions and half personal charges such as homosexuality, drunkenness, and criminal records. He said that, although the number of cases has decreased, the percentage of clearances remains about the same.

U.S.-Soviet Cooperation

The U.S. Government has offered to enter into an agreement with the U.S.S.R. under which Soviet and American planes would fly between Nome, Alaska, and Murmansk in the U.S.S.R. for observation of Arctic ice in connection with the International Geophysical Year. The reciprocal agreement would include exchanges of landing rights and the use of equipment, facilities, and personnel related to the flights.

At the Arctic conference of the IGY in Stockholm in May 1956, the U.S. National Committee for the IGY had suggested coordination of the ice observation flights of the two countries. The Soviet representatives then proposed that alternate flights be exchanged "in order to obtain a more comprehensive photographic record of the polar icepack and its changes."

New ARDC Research Branch

The Air Research and Development Command has established a new branch to conduct research, development, evaluation, and integration of flight-control systems displays in all Air Force aircraft. The new design engineering branch of the Flight Control Laboratory at ARDC's Wright Air Development Center, Dayton, Ohio, will carry out plans of the Control-Display Integration Working Group, which is composed of representatives from several laboratories and other units at WADC concerned with aircraft instruments.

The new branch is headed by C. J. Snyder and is composed of three sections: the display engineering section, with Jack Kearns as chief, which conducts research and development on whole panel instrumentation concepts for new weapon systems; the systems integration section, headed by Maj. B. S. Emrick (who is also chairman of the Working Group), which conducts research and development on problems of integration of whole panel instrumentation concepts with other subsystems; and the specifications and standards section, under John Hart, which provides engineering guidance and formulates general requirements for test procedures, acceptance standards, and reliability criteria.

News Briefs

■ The ministers of education of Central America recently took part in a meeting at which all five of the republics represented agreed to coordinate their systems of instruction. The participants have agreed to meet again on 5 Dec. in San Salvador to work out arrangements for a permanent organization to be established in Managua under the auspices of the Organization of Central American States.

■ The U.S. Atomic Energy Commission has announced that a hearing on the safety of the reactor being constructed by the Power Reactor Development Company of Detroit, Mich., will be held in Washington, D.C., on 13 Nov. Jay A. Kyle, assistant chief hearing examiner for the Federal Communications Commission, will be the presiding officer.

■ The effective tagging of fleas with radioactive isotopes for the study of the epidemiology of plague has been reported by the University of California Medical Center and the U.S. Public Health Service's communicable disease laboratory in San Francisco. Cerium-144, an isotope of one of the rare earths, has proved a practical and simple tracer for fleas, which heretofore have been especially difficult to tag. With the new technique, fleas can now be released on wild rodents and their life-cycle can be studied with radiation-detecting equipment.

Scientists in the News

THOMAS M. RIVERS of New York City, formerly vice president of the Rockefeller Institute for Medical Research, has been appointed medical director of the National Foundation for Infantile Paralysis. He succeeds HART E. VAN RIPER, who is leaving the National Foundation on 31 Oct. to become medical director of Geigy Pharmaceuticals of Ardsley, N.Y.

Rivers, who has been closely associated with the development and testing of the Salk vaccine, takes over his new post on 1 Nov., 1 year after joining the National Foundation's professional staff as assistant to the president of the foundation.

The following scientists received awards during the American Chemical Society's 130th National Meeting.

ROBERT B. WOODWARD, professor of chemistry, Harvard University, the ACS award for creative work in synthetic organic chemistry, sponsored by the Synthetic Organic Chemical Manufacturers Association, "for brilliant achievements in the synthesis of alkaloids."

WARREN K. LEWIS, professor emeritus, Massachusetts Institute of Technology, the ACS award in industrial and engineering chemistry, sponsored by the Esso Research and Engineering Company, "for his major part in developing fluidized bed systems for gas-solid contacting and chemical reactions."

MELVIN CALVIN, professor of chemistry, University of California, the ACS award for nuclear applications in chemistry, sponsored by the Nuclear Instrument and Chemical Corporation, "for skillful and diverse demonstrations of the power of radioisotopes in experimental chemistry."

GILBERT J. STORK, professor, Columbia University, the ACS award in pure chemistry, sponsored by Alpha Chi Sigma Fraternity, "for extraordinary work in the structure and stereospecific synthesis of natural products."

Ralph H. MÜLLER, staff member, Los Alamos Scientific Laboratory, University of California, the Beckman award in chemical instrumentation, sponsored by Beckman Instruments, Inc., "for a long series of 'firsts' in better ways to get chemical information from physical measurements."

STUART PATTON, associate professor, Pennsylvania State University, the Borden award in the chemistry of milk, sponsored by the Borden Company Foundation, Inc., "for ingenious application of organic chemistry techniques to problems of heat-induced deterioration of milk."

HAROLD A. SCHERAGE, associate professor, Cornell University, the Eli Lilly and Company award in biological chemistry, "for valuable additions to the knowledge of protein interactions and protein and macromolecular structure."

JOHN H. YOE, chairman, department of chemistry, University of Virginia, the Fisher award in analytical chemistry, sponsored by the Fisher Scientific Company, "for pioneering work in colorimetric analysis and organic analytical reagents."

D. H. R. BARTON, Regius professor of chemistry, University of Glasgow, the Fritzsche award, sponsored by Fritzsche

Brothers, Inc., "for many difficult structural elucidations of complex essential oils, particularly caryophyllene."

LUCY W. PICKETT, chairman, department of chemistry, Mount Holyoke College, the Garvan medal, "for developing pivotal information on molecular structure, especially through far ultraviolet spectroscopy."

DAVID H. KILLEFER, consultant, the James T. Grady award, "for many years of successfully spelling out chemistry for the lay and professional public, both young and old."

PETER DEBYE, professor emeritus, Cornell University, the Kendall Company award in colloid chemistry, "for important work on polymer solutions and solutions of soaps and silicates including development of pertinent light-scattering techniques."

C. GARDNER SWAIN, associate professor, Massachusetts Institute of Technology, the Precision Scientific Company award in petroleum chemistry, "for work in physical-organic chemistry of extreme importance to fundamental petroleum chemistry."

NORRIS W. RAKESTRAW, professor of chemistry, Scripps Institution of Oceanography, the Scientific Apparatus Makers award in chemical education, sponsored by Scientific Apparatus Makers Association, "for outstanding service to teachers of chemistry and chemical engineering."

G. ROBERT GREENBERG, associate professor of biochemistry, Western Reserve University, the Paul-Lewis Laboratories award in enzyme chemistry, "for unusual contributions to the knowledge of purine metabolism."

HUBERT L. ROSOMOFF, of the Naval Research Institute, Bethesda, Md., has won the American Academy of Neurological Surgery award for 1956. He has selected for his paper: "Hypothermia and cerebral vascular lesions, II, experimental middle cerebral artery interruption followed by the induction of hypothermia."

C. P. RHOADS, director of the Sloan-Kettering Institute for Cancer Research, New York, and scientific director of Memorial Center for Cancer and Allied Diseases, New York, has received the Walker prize of the Royal College of Surgeons, England. Scientists from all parts of the world, as well as from Great Britain, are eligible for this prize, which is awarded once every 5 years "for the best work in advancing the knowledge of the Pathology and Therapeutics of Cancer done, either partially or wholly, within the five years preceding the year in which the Prize is awarded." Rhoads was honored because he has had "a distinguished career as an experimental Pathologist and over the last ten years as the Scientific Director has built up at the Sloan-Kettering Institute and the Memorial Hospital, New York, the largest and most efficient cancer research organization in the world."

GEORGE W. BEADLE of the California Institute of Technology, retiring president of the AAAS, will deliver the Charles E. Dohme memorial lectures at Johns Hopkins University on 27, 28, and 29 Nov. The subject will be "The nature of the gene: (i) in heredity, (ii) in function, (iii) in evolution."

DAVID HOWE of Dallas, Tex., formerly associate plant physiologist at the Texas Research Foundation, has become agronomist for the research development and engineering staff of the Commercial Solvents Corporation. He will make his headquarters at the company's research laboratories in Terre Haute, Ind., where he will direct his attention to the development of agricultural chemicals products.

DAEL WOLFLE, executive officer of the American Association for the Advancement of Science, is in Hamburg, Germany, attending a seminar on science education that is being held by the UNESCO Institute for Education, 22–27 Oct.

HAROLD S. JOHNSON of Stanford University has been named associate professor of chemistry at California Institute of Technology.

Another appointment at C.I.T. is that of LEON BLITZER, who has been appointed senior research fellow in physics. On leave of absence from the University of Arizona, where he is professor of physics, he will conduct research in spectroscopy.

MASON R. BOUDRYE, associate professor of biology at Moorhead State Teachers College, has accepted the position of permanent executive secretary of the Minnesota Academy of Science. He is the first full-time secretary of the academy, whose offices will be at the Science Museum in St. Paul. After several years of planning, and through the support of the Louis W. and Maud Hill Family Foundation, the office has been established to further the activities of both the junior and senior academies.

E. FINLEY CARTER, formerly associate director of the Stanford Research Institute, has been appointed director of the institute.

MADISON D. CODY, professor of botany at the University of Florida, retired on 1 July.

HOWARD W. HAGGARD, director of the Laboratory of Applied Physiology at Yale University, has retired. An expert on alcohol and its problems, Haggard started Yale's internationally known Center of Alcohol Studies. He has had to curtail his activities in the past few years because of ill health, but he will continue to serve as an adviser to the laboratory and the center. He will also continue as editor of the *Quarterly Journal of Alcohol Studies,* a post he has held since the journal was established in 1940.

Haggard received his B.A. degree from Yale in 1914, after which he enrolled in the Yale School of Medicine, where he earned an M.D. degree in 1917. After serving as a captain of chemical warfare in World War I, he joined the Yale faculty in 1919 and, within a few years, became director of the Laboratory of Applied Physiology. From 1925 to 1940, he conducted an outstandingly popular lecture course in applied physiology that annually attracted an enrollment of more than 600 undergraduates. For many years he has been in constant demand as a lecturer.

In 1929 he published *Devils, Drugs and Doctors,* perhaps one of the first widely popular books on medicine. It was translated into many languages, including the Chinese, and for many years was a best seller. He was also the first person to conduct a weekly health program on radio with a regularly scheduled show started about 1934 over a New York station.

He was mainly instrumental in organizing the widely known Summer School of Alcohol Studies at Yale, now in its 14th year, and was also instrumental in establishing the Yale Plan Clinic, which set a nation-wide pattern for work with alcoholics.

From 1948 to 1950 he served as director of the Yale Office of University Development, during which period he toured the country twice, visiting nearly every Yale Club of alumni in the nation. Even before this time he was a successful fund-raiser for his laboratory. Colleagues estimate that during 30 years he raised more than $2 million for the laboratory and its projects.

A. S. BENENSON, lieutenant colonel, MC, USA, formerly director of experimental medicine at the Chemical Corps Laboratories in Camp Detrick, Md., has been appointed director of the division of immunology, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D.C. LOUIS H. MUSCHEL, major, MSC, USA, has also recently been assigned to the division of immunology. Previously he had been at the 406th Medical General Laboratory of the U.S. Army in Japan.

ELSA KEILES, formerly executive secretary of the metabolism and nutrition study section and the human embryology and development study section of the Division of Research Grants, National Institutes of Health, has recently joined the staff of the grants and training branch of the National Heart Institute.

CHARLES D. SHIELDS has been appointed associate dean of the Georgetown University School of Medicine (Washington, D.C.). Shields has been professor and chairman of the department of physical medicine and rehabilitation at the school since 1954. He will retain that post in addition to the deanship.

LAUREN B. HITCHCOCK has announced that he will resign as president and managing director of the Air Pollution Foundation, Los Angeles, Calif., on 15 Nov. to return to private practice as a management consultant in industrial research and development.

GEORGE S. CRAMPTON, ophthalmologist, teacher, and inventor, has received the 1956 gold medal award of the Illuminating Engineering Society. Although a physician, he is a past-president of the IES. He was accepted for membership 40 years ago because of the special lighting features he devised for each of his prismatic viewing instruments.

Crampton, who is 82, has been a surgeon at Wills Eye and Pennsylvania hospitals, Philadelphia, and is an emeritus professor of ophthalmology at the Graduate School of Medicine, University of Pennsylvania. He now owns and operates the Lenox Instrument Company in Philadelphia.

JOHN D. PORTERFIELD, a career officer of the Public Health Service since 1939 and at present director of the Ohio Department of Mental Hygiene and Correction, has been named assistant to the Surgeon General of the Public Health Service. He will have responsibility for planning and developing new programs, for providing a continuous appraisal and evaluation of existing activities, and for advising on proper balance among the various programs of the service. He will give particular attention to the fields of chronic diseases and aging, in which a variety of programs are developing.

PAUL J. FLORY, professor of chemistry at Cornell University, has been chosen to head the Mellon Institute's investigational activities as executive director of research. He will join the organization for a day a week during this fall, half time in February, and full time in the summer of 1957.

Recent Deaths

HOWARD W. BRUBAKER, Manhattan, Kan.; 79; professor emeritus of chemistry at Kansas State College; 25 Sept.

WILLIAM B. COLEMAN, Philadelphia, Pa.; 68; metallurgist; 30 Sept.

GEORGE A. DAVIS, Mountain Lakes, N.J.; 60; technical director of the Wilputte Coke Oven Division of the Allied Chemical and Dye Corporation; 9 Oct.

RALPH L. DOURMASHKIN, New York, N.Y.; 65; former senior surgeon with the U.S. Public Health Service; 10 Oct.

CAMILLE E. DREYFUS, New York, N.Y.; 78; chemist, chairman of the board of the Celanese Corporation of America; 27 Sept.

HENRY P. FAIRCHILD, New York, N.Y.; 76; professor emeritus of sociology at New York University; 2 Oct.

RICHARD FAIREY, London, England; 69; executive chairman of the Fairey Aviation Company; 30 Sept.

DONALD B. GILLIES, Cleveland, Ohio; 83; vice president of the Republic Steel Corporation until 1948; 29 Sept.

FREDERICK W. HODGE, Santa Fe, N.M.; 91; retired director of the Southwest Museum; 28 Sept.

GORDON F. HULL, Hanover, N.H.; 86; professor emeritus of physics at Dartmouth College; 7 Oct.

HANS S. JOACHIM, Boston, Mass.; 65; physicist at Watertown Arsenal; 7 Oct.

JUSTIN F. KIMBALL, Dallas, Tex.; 84; former vice president of Baylor University in charge of the College of Medicine, the School of Nursing, Baylor Hospital, and the College of Dentistry in Dallas; 7 Oct.

GEORGE M. ROSENBLUM, Merrick, N.Y.; 49; electronic engineer; 25 Sept.

ARCHIBALD SHARPE, London, England; 75; biologist; 4 Oct.

Education

■ The U.S. Office of Education has announced approval of the first two contracts for cooperative educational research in its history. The contracts, with Indiana University and with Vanderbilt University, will be financed from a recent appropriation of $1,020,000 for research by colleges, universities, and state agencies in the problems of education. Several other projects are under active consideration.

Indiana University will undertake an 18-month investigation to determine why only one-fourth of the top 10 percent of the state's high-school graduates in 1954–55 entered college. Also, studies will be made to learn how many of the top 20 percent of the state's 1955–56 high-school graduates do not continue their educational programs into college, and why they do not.

Wendell W. Wright, Indiana's vice president, with Christian W. Jung, associate professor of education and director of the university's summer session, will direct the $15,900 program. About one-third of the cost will be provided by Indiana University.

Vanderbilt University will conduct, under the direction of Albert J. Reiss, Jr., professor and chairman of the department of sociology and anthropology, a 3-year study of causes of juvenile delinquency. The study will be made among children in grades 7 through 11 in Nashville and in Davidson County, Tenn., with the cooperation of public, private, and parochial schools and community agencies. Information will be solicited from teachers, parents, attendance officers, juvenile court officials, and other citizens. Federal funds totaling $49,060 are planned for the Vanderbilt project.

■ The first annual training institute of the American Group Psychotherapy Association will be held on 9 Jan. 1957 at the Henry Hudson Hotel, New York, N.Y. This will be a 1-day meeting consisting of morning, afternoon, and evening sessions. The institute will be open to AGPA members, psychologists, and social workers who meet the minimum requirements for AGPA associate membership. The fee for participants will be $15 for members and $20 for nonmembers. This includes registration, tuition fees, and also dinner in the evening. For further information write to: Director of Training Institute, Room 300, 345 E. 46 St., New York 17, N.Y.

■ The University of Pennsylvania has begun construction of its William H. Donner Center for Radiology. It expects to complete the project in 1957 or early in 1958. Physicians, chemists, and physicists will carry on cooperative research projects in the new three-story building, for which the Donner Foundation has allocated $750,000.

■ Rensselaer Polytechnic Institute is planning a program that would make possible an increase in its undergraduate enrollment of 80 percent and an increase in its classroom and laboratory buildings of 50 percent. The expansion, which will be under way in the near future, is scheduled for completion during the next 14 years.

The 80 percent jump in enrollment would mean about 2450 more undergraduate students than are now in attendance. This would bring R.P.I.'s undergraduate enrollment to more than

5200 students. Present undergraduate enrollment is about 3000. To carry out the program, the institute must acquire an additional $24.5 million in endowments and $8 million for the construction of new classroom and laboratory buildings. Also, it will be necessary to borrow, on a self-liquidating basis, several millions of dollars for the construction of living quarters for students.

In announcing the program, Livingston W. Houston, president of Rensselaer, defined the institution's stand on the question of expansion. This has been a controversial subject among educators, some of whom have held that accepting a much larger number of students would impair the quality of education. Houston said:

"The leading engineering schools cannot lower their standards. All of us are seeking quality. The real problem is not one of simply maintaining quality but of producing high-quality students in the quantity that industry must have. Bigness and quality are not mutually exclusive. If they were, many of our leading larger companies would have ceased growing long ago. . . . [However,] faculty and facilities—and funds to support them—will be of little avail unless there are adequate numbers of properly qualified high school graduates available to enter our engineering colleges."

Grants, Fellowships, and Awards

■ The National Science Foundation is inaugurating a program for the support of instrumentation for chemical research. The purpose of this program is to provide either a portion or all of the funds required to purchase certain equipment that is needed for research in chemistry departments of American colleges and universities and cannot be obtained from any other source.

Chemistry departments of institutions interested in applying for grants should submit proposals that provide the following information: (i) name and address of institution; (ii) description of desired equipment; (iii) description of research of staff members who will utilize the equipment; (iv) biographic data of staff members concerned; (v) arrangements to be made for care and maintenance of the equipment; (vi) related equipment on hand; (vii) budget (include statement of funds, if any, from other sources).

Fifteen copies of the proposal should be submitted to the National Science Foundation, Washington 25, D.C., attention Mathematical, Physical and Engineering Sciences Division. One copy should be signed by the chairman of the department and by an official authorized to sign for the institution. All copies should indicate the persons, with titles, who have signed the single copy. Proposals received *by 1 Dec.* will be considered for grants to be awarded by about 1 Mar. 1957.

■ The U.S. Atomic Energy Commission has announced the award of 50 unclassified life science research contracts in medicine, biology, biophysics, and radiation instrumentation. Ten of the awards, each of which covers a period of 1 year, are new projects; three are in medicine, six in biology, and one in radiation instrumentation. Forty contract renewals have been negotiated to allow for continuation of research already in progress; 19 of these are in the medical sciences, 16 in biology, three in biophysics, and two in radiation instrumentation.

■ Expanded aid to outstanding high-school physics, chemistry, and mathematics teachers has been announced by Shell Companies Foundation, Inc., New York. The foundation this year provided Shell Merit Fellowships for 60 high-school teachers at seminars conducted by Stanford and Cornell universities this past summer. This program was so successful that Shell plans to provide a significantly greater number of fellowships for 1957.

More than 2000 teachers from all parts of the United States applied for the fellowships available in 1956. Fellowship teachers received allowances for travel costs to Stanford or Cornell, tuition fees, living expenses, and $500 in cash to offset loss of potential summer earnings. Teachers attended lecture and laboratory sessions, had group discussions with leading specialists in their various fields, and visited nearby scientific installations.

Requests for fellowship applications should be sent directly to the two universities. Mathematics, physics, or chemistry teachers with 5 years of experience and known leadership ability are eligible. Teachers living west of the Mississippi should write the School of Education, Stanford University, Stanford, Calif. Teachers east of the Mississippi should write the Department of Education, Cornell University, Ithaca, N.Y.

■ During the years 1957–58 the Office of Naval Research will continue its modest program in support of basic research in astronomy and astrophysics. As in past years, the National Research Council Committee on Astronomy Advisory to ONR, with a membership of seven astronomers nominated by the council of the American Astronomical Society, will aid ONR in evaluating proposals received.

Applicants must submit proposals *by 15 Dec.* Ten copies of each proposal, which should include a full description of the project and a cost breakdown, should be addressed to: Chief of Naval Research, Department of the Navy, Washington 25, D.C., Attention: Code 430. Letters of recommendation will be helpful to members of the advisory committee in making their appraisal and should be sent by the writer directly to the above address.

It is expected that the advisory committee will again recommend a maximum overhead charge of 15 percent of the total budget. The cooperation of universities in approving overhead rates of this order will in no way prejudice negotiations of overhead for other contracts.

■ The Exploration Fund of the Explorers Club, New York, made its first grant to a nonmember of the club under its new unrestricted award policy when it recently voted to support the anthropological researches of Neville Dyson-Hudson and V. R. D. Dyson-Hudson in East Africa. The $1231 grant is to cover study of the hill tribes fringing the Karamoja plateau. The Exploration Fund was established by C. R. Vose and was open only to members of the club until this year.

■ The U.S. Public Health Service has reported that almost $1 million has been awarded to schools and individuals through a new public health training program. Under the program, which was authorized by Congress on 23 July, 261 public health workers are now enrolled for graduate training in 41 schools. Upon completion of their studies, most of the trainees will be employed in state and local health departments, thus helping to relieve the acute personnel shortage.

In the Laboratories

■ Last month the Westinghouse Electric Corporation dedicated the new Westinghouse Research Laboratories, which are located on a 72-acre site in Churchill Borough, Pa., 10 miles east of Pittsburgh. The three-story, L-shaped building houses the laboratories, offices, shops, and other requirements for a staff of more than 700 people. Included in these facilities are a technical library containing 30,000 volumes and subscribing to more than 500 periodicals; a complete metals processing laboratory for melting, annealing, rolling, and otherwise processing metals and alloys; an instruments laboratory; several machine shops; a glass blowing laboratory; a photographic and reproduction department; drafting facilities, and so forth.

Although the structure has just been completed, work has already begun on an additional wing that will increase its size by nearly 50 percent and will provide accommodations for the materials engineering department. In addition,

Westinghouse Research Laboratories in Churchill Borough, Pa.

plans for a nuclear reactor have been announced, the first to be built by a single industrial company for its own research. The reactor, which will be located near the new facility, will be in operation in about 2 years.

The departments that occupy the new building, and the respective department managers, are as follows: chemistry, R. W. Auxier; electromechanics, C. R. Hanna; electronics and nuclear physics, J. W. Coltman; insulation, J. Swiss; magnetics and solid state physics, J. K. Hulm; mathematics, M. Ostrofsky; mechanics, R. E. Peterson; metallurgy, J. H. Bechtold; physics, L. J. Varnerin; semiconductor and solid state physics, E. N. Adams; and technology, J. C. R. Kelly. During a prededication press tour of these departments a number of new developments were announced.

An advanced steam turbine for electric power generation was described. Steam, under a pressure of 16,000 pounds per square inch and a temperature of 1200°F, is being used to test the strength of the stainless steel casing that will house the pressure element of the new turbine. The turbine and the generator it drives will constitute a turbo-generator unit rated at 325,000 kilowatts, enough electric power to supply all the residential needs of a city of about 1 million people.

After a demonstration of electroluminescence (light by phosphors coated on a glass panel that is treated to conduct electricity) a room lighted by electroluminescence was unveiled. Some 112 glass panels, each 1 foot square in size and giving off a soft green light, are used to illuminate the room with shadowless, fixtureless light. Two control knobs, one for brightness and the other for color, make is possible to adjust for any level of brightness, and to create any color atmosphere, from varying shades of white to blue or red.

A new electronic brain, the Automex, was also described. The device has a "built-in intelligence," enabling it to distinguish between right and wrong decisions. It decides at every step whether the step just taken was correct or not; the next step is based on this decision and is the one most likely to lead to success.

Another instrument that was announced is a new type of gyroscope, the vibragyro, that is designed to stabilize aircraft in flight. It is the product of 2 years of research aimed at developing a unit lighter and more rugged that the conventional rotating-type gyro that is now generally in use.

A new, high-temperature, high-voltage insulating material is another development relating to aircraft that was exhibited. The insulation, a solventless silicone resin that was developed in cooperation with the Dow Corning Corporation, can be formed into thick sections of solid, heat resistant insulation for use in complex electrical equipment. By eliminating the solvent formerly necessary in other heat-resistant resins, it was possible to produce an insulation that is entirely free of air spaces, or 'bubbles.'

The Westinghouse Research Laboratories are devoted 90 percent to basic and fundamental research. Only 10 percent of the work in the new laboratory is in applied research. Fifty percent of the work is on what Westinghouse designates as basic research, the search for new knowledge in fields that relate directly to the company's business; 40 percent, at a cost of $2.5 million this year, is on fundamental research—work in fields of science basic to the electrical industry, but on specific projects that have little or nothing to do with the company's business as such. Over-all, Westinghouse is spending $150 million during the current year on its total technical effort, including both research and development.

■ The Helipot Division of Beckman Instruments, Inc. has announced completion of its move from South Pasadena, Calif., and its vicinity to temporary quarters in Costa Mesa in preparation for the occupation of a new $2-million plant in Newport Beach early next year. The move consolidates 16 Helipot facilities that were located in South Pasadena, Pasadena, Alhambra, and San Gabriel. Helipot, which manufactures precision components for electronic instruments and systems, will continue to direct plants and offices in Mountainside, N.J., and Toronto, Canada, from the new headquarters.

■ The Food Machinery and Chemical Corporation, New York, has announced the formation of the FMC Organic Chemicals Division, which will be responsible for the manufacture and sale of all plastics produced by FMC and of all organic chemicals that are not directly linked with the operations of one of the company's other chemical divisions. Henry S. Winnicki, formerly director of engineering and development for FMC Chemicals, has been named president and manager of the new division, which will have quarters in New York.

■ The St. Eloi Corporation, Newtown, Ohio, has prepared a brochure, which will be distributed free on request, that presents a tabulation of the physical properties of the lanthanide metals and oxides. The brochure also announces the inauguration of the company's pure rare earth metal production program, which will make the entire group of lanthanide elements available to industry and academic laboratories.

■ Experiments designed to utilize atomic radiation to create or improve petroleum products and processes will be centered in a new atomic radiation laboratory to be constructed by the Continental Oil Company in Ponca City, Okla., at a cost of approximately $500,000. The new laboratory, which is expected to be completed by March 1957, was designed by the Walter Kidde Nuclear Laboratories.

Book Reviews

Fertilization. Lord Rothschild. Methuen, London; Wiley, New York, 1956. 170 pp. Illus. $3.50.

The stimulus that the fertilizing spermatozoon provides to the egg is well matched by the stimulating effect that this book is likely to have on research in its particular field and in biology in general. The special excellence of the present work evidently results from the fact that the author is one of the foremost investigators in the field and, at the same time a lucid, thoughtful, writer of broad general knowledge.

The book is pitched at a level that presupposes some knowledge of general cytology, physiology, and biochemistry. It will, of course, be especially valuable to students and to investigators of animal and plant reproduction. However, it should also be of considerable interest and value to all biologists, to scientists in general, and to educated laymen. For biologists in certain fields, such as virology, enzymology, cellular metabolism, immunology, bioelectricity, the discussions of correlative phenomena in the sperm-egg systems should prove highly nutritive. For the general reader, the book will be a source of enjoyment and information concerning a subject about which he has undoubtedly puzzled since the day he first asked his mother, "Where did I come from?"

The book opens with a descriptive section on some of the morphological changes that occur upon fertilization. This is followed by chapters dealing with interacting substances of eggs and sperm, metabolism of eggs, chemical and physical changes upon fertilization, polyspermy, bioelectricity, and specificity. A short last section lists a number of subjects, in addition to those suggested in the body of the text, that the author considers to be worth further investigation.

The author has not attempted to review all available papers dealing with the various topics he discusses, since he justly considers this inappropriate for a volume of the present size and scope. However, the work is very well documented, with a literature list of 497 titles which include papers that are as current as possible. A classified index is included of plants and animals mentioned in the book. This is to help the reader, where necessary, identify the organism with respect to class or order and also to resolve some of the confusion arising from synonyms.

Of particular significance is the fact that the work is no mere recital of summaries of papers dealing with fertilization, but an analytic treatment of various problems, including valuable suggestions and ideas of the author. Evaluations are given of the extent to which various investigations have furthered knowledge of particular problems. Often this involves critical assessment of various experiments and it is of interest to note, in this regard, that Rothschild applies the same objectivity toward his own investigations as he does toward those of others.

ALBERT TYLER
California Institute of Technology

Physics and Mathematics. Series I. *Progress in Nuclear Energy.* R. A. Charpie, J. Horowitz, D. J. Hughes, and D. J. Littler, Eds. McGraw-Hill, New York; Pergamon, London, 1956. 398 pp. Illus. $12.

This book contains selected papers and digests of papers from the International Conference on the Peaceful Uses of Atomic Energy held in Geneva, August 1955. Some effort has been made to correlate data, experimental methods, and theory in the nuclear and reactor physics fields from the various contributing nations. The first six chapters deal with microscopic behavior of fissionable and other reactor materials; the remaining five chapters deal primarily with theory and experiment on various types of nuclear reactors—homogeneous, thermal, fast, heterogeneous, and intermediate.

Chapter 1 provides a summary of fuel cross sections and neutron yields. It is noted that there still remain surprisingly large discrepancies between measurements made at different installations. Chapter 2 describes methods of measurement of fuel resonance cross sections. The graphs contained in this section contain less detail than those found in the book *Neutron Cross Sections,* BNL-325. Chapter 3 is a Geneva paper giving the present theoretical basis of neutron resonances. Chapter 4 is a new review of methods of measuring scattering cross sections. Chapter 5 discusses the measurement of cross section for xenon-135. Chapter 6 lists resonance capture integrals for many elements of interest in reactor design.

Chapter 7 summarizes all existing data on delayed neutrons but does not resolve the recurring problem facing the reactor designer, namely, the best choice of half-lives and yields. Chapter 8 reviews the experimental data on homogeneous critical assemblies and those with nonuniform fuel distributions. Chapter 9 presents for the first time in one place outlines of methods for analyzing fast reactors and gives a correlation with measurements at Los Alamos and Argonne and in England. Chapter 10 is a Soviet paper on heterogeneous reactors using integral and summation methods. These approaches are not as familiar to American reactor physicists as diffusion methods. Chapter 11 compares theoretical methods of treating intermediate reactors and experimental data on systems designed to test the theories.

I was interested in ascertaining the amount of correlation of international results that appears in this new book and was disappointed to find that it consists essentially of selected reprints. Because of the importance of the Geneva conference in the area of nuclear engineering and science, it is very likely that greater use will be given to the original volumes than to this book. Only in about four chapters is there any analysis and comparison of papers presented at the conference. It may be, however, that this book will serve a useful purpose in calling the attention of the more casual reader to papers agreed to be of greatest importance in the field.

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Progress in Neurobiology: I, Neurochemistry. Saul R. Korey and John I. Nurnberger, Eds. Hoeber-Harper, New York, 1956. 244 pp. Illus. $6.75.

This excellent volume represents the proceedings of the first of a series of symposia on neurochemistry organized by Saul Korey and John Nurnberger and held in conjunction with the annual meetings of the American Neurological Association. The editors have shown sound judgment and foresight in addition to a willingness to expend considerable effort in a realization of this concept.

Although the volume consists of a series of apparently unrelated but excellent papers, there is considerable com-

prehensiveness in the representation of important areas. One finds an excellent review by Palay of new knowledge of neuronal structure achieved through electron microscopy, which biochemists are beginning to realize must form the framework in which chemical systems contribute to function. The chemical structure of the nervous system is represented by papers on the chromatographic properties of sphingosine by Wittenberg, on the structure of ribonucleic acid by Rich, and on fractionation of brain copper protein by Porter and Folch-Pi.

Some fundamental aspects of intermediary metabolism are discussed by Roberts on the formation and utilization of γ-aminobutyric acid, on enzymatic thioltransacetylation by Brady and Stadtman, on acetal phospholipids by Korey. The relationships of biochemistry to development are discussed in papers on adaptive enzyme formation in morphogenesis by Gordon, on developmental changes in enzymatic activity by Jordan and his associates, and on studies of over-all cerebral metabolism in children by Kennedy.

Biochemical mechanisms and their role in the functional activity of the nervous system are treated by papers on the biochemical correlates of stress by Nurnberger and Gordon, on acetylcholine activity by Wilson and Altamirano, and on cerebral metabolism and mental activity by Sokoloff. A number of papers discuss the biochemical correlates of neurological disease, including Wilson's disease by Scheinberg, epilepsy by Tower, and allergic encephalomyelitis by Goldstein and Kies.

The organizers of this symposium are to be congratulated for the role that they are playing in the ever-widening acceptance of the important place that biochemistry occupies in modern neurology.

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Handbook of Scientific and Technical Awards in the United States and Canada. Margaret A. Firth, Ed. Special Libraries Association, New York, 1956. 491 pp. $10.

This selected listing of the most important awards presented by the leading scientific and technical societies in the United States and Canada is arranged alphabetically by names of the societies listed. The basic list used for the compilation was edition 8 of *Handbook of Scientific and Technical Societies of the United States and Canada,* 1948. All societies listed as presenting awards were reviewed. Awards granted by foundations, publishers, universities, and companies are not included in this compilation.

Under each society listed the names of that organization's awards are arranged in alphabetical order. A brief description of each award is given, and information is included on the criteria for selecting recipients and the nature of the award (monetary, a medal, a citation).

An index to the listings of the United States and Canadian societies, a subject index of the awards, and a combined index of award titles and recipients are included. This compilation will fill a useful place on many reference shelves.

Alcoholism as a Medical Problem. A conference held under the auspices of the Committee on Public Health of the New York Academy of Medicine and the New York State Mental Health Commission. H. D. Kruse, Ed. Hoeber-Harper, New York, 1956. 102 pp. $3.

This small book represents the material presented at a conference held under the auspices of the Committee on Public Health of the New York Academy of Medicine and the New York State Mental Health Commission. The material is edited by the executive secretary of the Committee on Public Health, and he also writes the preface to the book. There are eight chapters, which are the eight different papers presented at the meeting; included also is a certain amount of discussion by the 30 participants of the conference.

The purpose of this volume is best stated by quoting from the preface: "The sponsors of the conference had definite objectives: to introduce the problems of alcoholism to the physician; to create in him an appreciation of the magnitude of the disease with its frightening and tragic consequences; to direct his attention to his new responsibility to the alcoholic and to encourage him to assume it; to acquaint him with the basic medical facts and principles about alcoholism; and to stimulate research on the causes of this disease, and on the care and treatment of the patient."

This book has much excellent material in it, and it is difficult to decide which material to emphasize in a review of it. Chapter 1, "The epidemiology of alcoholism," is by John E. Gordon, professor of epidemiology, School of Public Health, Harvard University. Gordon's approach is somewhat different from the conventional approaches on the subject, and it is worth discussing in some detail. He maintains that alcoholism should be studied in the same manner as other diseases, such as tuberculosis. He would therefore approach the problem by dividing the population into those who use alcohol as a beverage and those who do not use it at all. This he feels corresponds more properly with the public-health approach to such problems as tuberculosis and poliomyelitis. He compares it in this respect with poliomyelitis, nine-tenths of the cases of which he feels do not produce clinical recognition and are not actually medical problems.

He concludes: "A majority of adults in this country use alcohol. Abstinence is therefore not the norm. What part corresponds to infection and what part to disease? The more significant consideration is what part of infection is truly latent, ending benignly or conceivably even with benefit to the host, and what part is merely incubatory infection, destined to evolute into actual disease. More directly, what proportion of users of alcohol will eventually become alcoholics and what are the factors of host and environment that determine that result?"

Then follows an interesting discussion of the biologic gradient of alcoholism, the ecology of alcoholism, and control. Under this last heading he states: "No mass disease of man has ever been adequately controlled by attempt to treat the affected individual. Some progress can be made, there are ethical reasons for that approach, but if the objective is control of the condition in a population the fundamental approach is through definition of the nature and extent of the problem, the recognition of causative factors, and prevention. A program based on treatment of the exaggerated illness is temporizing and with no great promise of productive result; it is good clinical medicine but poor public health."

This conclusion seems to me to be of the greatest importance. At the present time there are many who wish to attack the problem of alcoholism merely by setting up more treatment facilities for the care of extreme cases of alcoholism. It is most important to emphasize the public-health approach and to warn all those who are now trying to do something about alcoholism that simply setting up more facilities for the treatment of alcoholics is never going to solve the problem of alcoholism.

Chapter 2, "Views on the etiology of alcoholism—I, The organic view," is by Harold E. Himwich, director of research, Galesburg State Research Hospital, Galesburg, Illinois. Himwich presents an interesting discussion of the theories of organic etiology, of the pharmacology of alcohol, and then attempts to discuss the organic basis for addiction. He points out that there are physiological mechanisms which are changed as a reaction of the organism to various substances and states: ". . . enzymatic changes in response to alteration of diet have also been found in mammals as well as in rats

and dogs. The part played by alcohol is further demonstrated because these disturbances can be corrected by taking more alcohol. The abstinence syndrome reveals that a pharmacologic substance, alcohol, assumes the role of a dietary requirement. Such a viewpoint places delirium tremens in the category of a withdrawal syndrome." Himwich therefore thinks of alcoholism as much more akin to opium. He likewise believes that these findings indicate that the presently generally accepted idea of immediate and complete withdrawal of alcohol is undesirable and may even throw the patient into delirium tremens. He agrees that this concept is not generally accepted, but wishes to advocate it again. Whether or not one agrees with him, it is worth while having this question brought up again and reevaluated. He concludes: "The physiologic factor is regarded as structural and active when the cells of the body and particularly those of the brain appear to function better in the presence of alcohol than in its absence."

Chapter 3, "Views on the etiology of alcoholism—II, The psychodynamic view," is by Franz Alexander, clinical professor of psychiatry, University of Illinois. Alexander's approach is primarily the orthodox psychoanalytic viewpoint, quoting heavily from Knight. He emphasizes the disinhibiting effect of alcohol which reduces repressions and permits a freer expression of ego-alien, mostly infantile cravings. He mentions oral dependent needs, latent homosexuality, repressed or inhibited heterosexual and hostile impulses, as the most important of these.

Chapter 4, "Views on the etiology of alcoholism—III, The behavioristic view," is by Edward Joseph Shoben, Jr., associate professor of education, Teachers College, Columbia University. He holds that alcoholism can best be studied as maladaptive behavioral adjustment. He agrees to the apparently universal viewpoint of the participants that alcohol reduces anxiety. He questions whether drinking releases lower functions and suggests that it rather releases impulses that have been inhibited by anxiety. He believes that important material can be obtained by studying the availability and first drinking experiences of the alcoholic in learning how alcohol has been chosen as a defense against anxiety.

Chapter 5, "Views on the etiology of alcoholism—IV, The Sociologic View," is by August B. Hollingshead, professor of sociology at Yale. He points out that sociologists have shown little interest in the etiology of alcoholism but have studied mostly the use and abuse of alcohol in particular cultures. Although he feels that there is evidence of varying use of alcohol with different cultures, he does not believe that such studies have shown what is the specific factor operating in a given situation that led to alcoholism in an individual. He also criticizes the sociological studies for seeking etiology factors in social and cultural situations and largely overlooking the individual.

Chapter 6, "The natural history of alcoholism—I, Its onset and course," is by Arnold Z. Pfeffer, assistant clinical professor of psychiatry, New York University School of Medicine. This chapter is a rather orthodox medical and psychiatric discussion of alcoholism.

Chapter 7, "The natural history of alcoholism—II, Its psychopathologic manifestations," is by S. Mouchly Small, professor of psychiatry, University of Buffalo School of Medicine. Here we get a fairly textbooklike description of the different types of alcoholic mental disorders.

Chapter 8, "Evaluation of the treatment of alcoholism," is by Hugo Muench, professor of biostatics, School of Public Health, Harvard University. Muench points out that up to 50 different treatments are listed for alcoholism and that medical schools commonly teach that the more and more varied the treatment for a disease, the less likely that any one of them has any particular value. He goes on to a discussion of simple statistical criteria for dealing with such a study. There is further discussion of the meaning of "effects of treatment" and a plan for setting up a life-table study.

There are many interesting discussions of these papers by other members of the conference. On the whole, it can be said that this book is somewhat unique and different from any of the recent small books on alcoholism that have come out, that it emphasizes that alcoholism is a medical problem, and that it presents a great deal of interesting material by a number of extremely well-qualified persons. The book is recommended for anyone who wishes to keep up to date on the whole problem of alcoholism.

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Handbuch der Physik. vol. 47, *Geophysics.* I. S. Flügge, Ed. J. Bartels, Group Ed. Springer-Verlag, Berlin, 1956. 659 pp. DM. 118.

Fifty years ago, a student could become familiar with all major results of physics of the atmosphere, the ocean, and the earth's interior within a year; today, no geophysicist has detailed knowledge of more than a few fields of geophysics. The greatest progress in geophysics has been made since the preceding edition of this handbook appeared about 1930. The present volume is actually a completely new book. In the preceding edition, geophysical chapters were inserted with corresponding chapters of physics—for example, the one on seismic waves in the volume on mechanics of elastic bodies. Now, there are two volumes devoted entirely to geophysics. The first of them, volume 47, covers only problems of the solid earth and is entirely written by new authors. Several of its chapters deal practically entirely with findings unknown in 1930 or discuss new conclusions from rediscussion of older observations.

The volume contains the following major topics: H. Spencer-Jones, rotation of the earth including discussion of the unit of time and of changes in the length of the day (23 pp.); J. Coulomb, theory and types of seismographs (in French, 51 pp.); K. E. Bullen, propagation of seismic waves through the earth, earthquake energy, elastic constants and density in the earth (43 pp.); M. Ewing and F. Press, surface waves and guided waves; the latter were practically unknown 20 years ago but begin to form a separate field of seismology (21 pp.); J. Coulomb, microseisms (in French, 13 pp.); M. Ewing and F. Press, fundamental problems of refraction and reflection methods of seismic prospecting (16 pp.); H. Baule and E. Mueller, methods to determine in the laboratory elastic and nonelastic properties and wave velocities in rocks and effects of temperature and pressure (in German, 32 pp.); G. D. Garland, absolute and relative determination of gravity, reduction of gravity observations, gravity anomalies and their interpretation (44 pp); M. Ewing and F. Press, structure of the crust on the basis of seismic and gravity measurements (12 pp.); A. E. Scheidegger, forces in the crust, which can be deduced from surface features, faulting, folding, distribution of continents and oceans, without "fantastic postulates" (30 pp.); J. T. Wilson, R. D. Russel, and R. M. Farquhar, radioactive decay, isotopes, radioactivity of rocks, age of minerals, duration of geologic periods, and age of the earth (76 pp.); J. A. Jacobs, the earth's interior, deduced from seismological data, expected effects of temperature, pressure, magnetic and electric properties (42 pp.); L. Cagniard, electric currents in the earth and electric prospecting (in French, 63 pp.); S. K. Runcorn, magnetization of rocks and paleomagnetism (28 pp.); S. K. Runcorn, the earth's magnetic field and its variations (36 pp.); K. Jung, figure of the earth, potential theory of the gravitational field, the geoid, gravity in the earth's interior, polar movement; extensive equations and tables (in German, 105 pp.). The book is highly recommended to everybody interested in geophysical problems.

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Meetings and Societies

Theoretical and Applied Limnology

The 13th congress of the International Society of Theoretical and Applied Limnology met in Finland from 27 July to 7 Aug. About 380 members and guests were registered from 38 countries, making this congress the largest in the history of the society. For the first time in many years, there was a good representation from the central and eastern European countries. Following the opening business session in Helsinki, the Edgardo Baldi memorial lecture, "Production, reproduction, and yield," was delivered by W. E. Ricker (Canadian Fisheries Research Board, Nanaimo).

The first 7 days of the meetings were devoted mainly to 120 short research papers; most of these were read in lecture rooms of the Forestry Building at the University of Helsinki. Contributions can be roughly grouped into six major categories: lake typology, fisheries, brackish waters and osmoregulation, lake and river pollution, botanical papers, and miscellaneous zoological papers.

Problems of lake typology were presented from a wide variety of chemical, physical, and biological viewpoints, and the discussions revealed a great divergence of opinion regarding the relative soundness of various typological criteria. Fish papers emphasized reproduction, spawning, and development. Brackish-water contributions dealt chiefly with osmoregulation and relative tolerances of fresh-water and marine invertebrates, especially in the Baltic and Mediterranean areas. In view of Finland's extensive paper industry, sulfite pollution of lakes and streams received special attention. Demonstration trips on the research vessel *Aranda* and sightseeing tours of the skerries off Helsinki were also conducted during the first week.

Following the Helsinki sessions, most of the congress registrants participated in a 5-day congress excursion in southwestern Finland by train, bus, and boat. A wide variety of lakes were visited as well as paper factories, pollution sites, and the Tvärminne Zoological Station in its unique situation in the complicated system of skerries of the Gulf of Finland.

Upon returning to Helsinki, the congress registrants met in final business session. U. D'Ancona (Italy) was elected president, and T. T. Macan (England) continues as secretary-treasurer. The 14th congress is scheduled to meet in Austria in 1959.

An 8-day post-congress excursion by train, bus, and boat took about 120 participants from Helsinki through eastern and northern Finland as far as Tornio or Kilpisjärvi. Noteworthy lakes and streams, as well as paper and plywood factories, polluted areas, copper mines, and hydroelectric stations, were visited.

An outstanding feature of the congress and the excursions was the precise timing and highly commendable organization, especially in view of the complex meal and travel facilities necessary for such a large group during field trips and excursions.

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Meeting Notes

■ At the recent meeting of the Ecological Society of America at Storrs, Conn., a Section of Animal Behavior and Sociobiology was formally organized. The purpose of this section is to advance, coordinate, and assist research and publications on the subject of animal behavior and social organization basic to theoretical science and human welfare, and to act as a liaison agency between workers in the various scientific fields concerned. At its first organizational meeting, the section elected the following officers: chairman, J. P. Scott of Roscoe B. Jackson Memorial Laboratory; vice chairman, A. M. Guhl of Kansas State College, and secretary, M. W. Schein of Pennsylvania State University.

The section immediately concerned itself with three major problems in the field of behavior studies: publications, terminology, and teaching. Lester R. Aronson, the American Museum of Natural History, was named as chairman of a committee to continue the search for new publication outlets for papers dealing with animal behavior. A. M. Guhl, Kansas State College, was appointed chairman of a Committee on Glossary and Terminology designed to help alleviate the confusion caused by coining new terms or misusing old ones. W. N. Etkin, Albert Einstein College of Medicine, was named as chairman of a committee to look into the needs and possibilities of publishing a textbook on animal behavior and sociobiology aimed at the upper-class or early graduate student level.

A tentative list of members of the section shows a wide variety of interests, covering every form of animal life as well as the more generalized biological fields. Persons interested in any phase of behavior studies are invited to become members. Any member of any class of the Ecological Society of America may become a member merely by writing to the secretary of the section; there are no additional dues. Others may join the section by becoming members of the Ecological Society (associate member: $2) and then informing the secretary of the section of their action. Further information may be obtained from the secretary.

■ Seventeen scientists from eight foreign countries will be among 52 leaders in ozone research who will speak at the first International Ozone Conference to be held in the United States. They will present 20 of the 60 papers on the fundamental and applied chemistry of ozone that will be delivered at the conference, which will take place 28–30 Nov. at the Sheraton Hotel in Chicago, Ill. The National Science Foundation is cooperating with Armour Research Foundation of Illinois Institute of Technology and other American sponsors in bringing the scientists to America. The speakers from each of the countries follow.

Germany. W. Partmann of the State Research Institute for Food Processing, Karlsruhe; R. Criegee, Institute for Organic Chemistry, Karlsruhe; and A. Ehmert of Max Planck Institute, Weissenau.

Switzerland. Albert Torricelli, a consultant on chemistry and hygiene in Berne; and Emile Briner of the University of Geneva.

France. P. Guinvarc'h, chief engineer of the Paris Municipal Water Works; P. Frison of Paris, water filtration plant engineer for Trailigaz, which builds and operates water plants; and Andre Bernanose of the University of Nancy.

England. R. M. Goody, department of meteorology, Imperial College, London; R. W. Lunt, honorary lecturer on chemical engineering, University College, London; and A. W. Brewer, Clarendon Laboratory, Oxford.

Japan. Hiroshi Otsuki, managing director of Nippon Ozone Company, Tokyo; E. Inoue, Tokyo Institute of Technology, and Y. Miyaka, of the Meteorological Research Institute, Tokyo.

Holland. J. P. Wibaut, director of organic chemistry research laboratory, University of Amsterdam.

India. N. A. Ramaiah, head of the department of physical chemistry, Indian Institute of Sugar Technology, Kampur.

Argentina. Hans Schumacher, director of the research institute at the University of LaPlata at LaPlata.

In addition, a paper prepared by L. Mester of the University of Technical Sciences at Budapest, Hungary, will be read.

American participants in the conference will represent a broad range of organizations concerned with developments in ozone research, including colleges and universities, research institutions, industrial concerns, and national and city government. A major purpose of the conference, according to its chairman, Clark E. Thorp, manager of Armour Research Foundation's chemistry and chemical engineering research department, will be consideration of industrial applications of ozone, both current and potential, as well as the fundamental chemistry of ozone and its biological effects. For additional information, write to Sidney Mittler, Armour Research Foundation, 10 W. 35 St., Chicago 16, Ill.

■ The seventh Conference for Agricultural Services in Foreign Areas, sponsored by the U.S. Department of Agriculture, the International Cooperation Administration, and the land-grant colleges, was held 22–24 Oct. in Washington, D.C. Other participants were the State Department, various private foundations, agricultural attachés of foreign embassies, and interested private firms.

■ The Flavor Laboratory of Arthur D. Little, Inc., will inaugurate, on 19 Nov., a series of symposia on flavor research as a part of the company's 70th anniversary celebration. The first symposium, to be held in Cambridge, Mass., will present a broad picture of the current state of flavor research and its industrial applications. Little has engaged in flavor and odor research for more than a quarter of a century. Because this field has grown so rapidly in recent years, A.D.L. is sponsoring this series of 1-day conferences to enable those with a professional interest in the field to keep abreast of developments.

At the first symposium, Lloyd M. Beidler, head of the physiology department at Florida State University, and Carl Pfaffman, professor of psychology at Brown University, will examine the basis of taste and smell. Taste testing in the laboratory and for consumers will be reviewed by Ernest E. Lockhart, scientific director of the Coffee Brewing Institute, and George F. Garnatz, director of the Kroger Food Foundation. Eric J. Hewitt, vice president of Evans Research and Development Corporation, will discuss applications of physiochemical research on flavor.

In the evening, the group will hear Richard L. Hall, McCormick and Company's research director; Robert Heggie, vice president of the American Chicle Company; and Robert K. Hower, research director of the National Biscuit Company, tell of positive approaches their companies have taken to flavor problems. Three other conferences concerned with laboratory flavor testing, consumer testing, and physiochemical research on flavor are planned for next year.

Society Elections

■ Arctic Branch, Alaska Division, AAAS: pres., Ivar Skarland, University of Alaska; v. pres., Charles J. Keim, University of Alaska; sec.-treas., Carol Juedes, Geophysical Institute, University of Alaska.

■ Association for Computing Machinery: pres., J. W. Carr, III, University of Michigan; v. pres., R. W. Hamming, Bell Telephone Laboratories; sec., J. Moshman, Bell Telephone Laboratories; treas., C. Concordia, General Electric Company.

■ Botanical Society of America, Inc., 1957; pres. George S. Avery, Brooklyn Botanic Garden, Brooklyn, N.Y.; v. pres., Paul Weatherwax, Indiana University; sec., Harold C. Bold, Vanderbilt University, Nashville 5, Tenn.; treas., Harry J. Fuller, University of Illinois, Urbana.

■ American Society of Parasitologists: pres., Gilbert F. Otto, Abbott Laboratories; pres.-elect, A. C. Walton, Knox College; v. pres., Allen McIntosh, Agricultural Research Service, U.S. Department of Agriculture; sec., Paul E. Thompson, Parke-Davis and Co.; treas., Robert M. Stabler, Colorado College.

■ American Society of Civil Engineers: pres., Mason G. Lockwood, Lockwood, Andrews and Newman, Houston, Tex. The vice presidents are Francis S. Friel, Albright and Friel, Inc., and Norman R. Moore, Mississippi River Commission.

Forthcoming Events

November

26–28. American Soc. of Refrigerating Engineers, Boston, Mass. (R. C. Cross, ASRE, 234 Fifth Ave., New York 1.)

26–30. Automation Exposition, 3rd intern., New York, N.Y. (TIAE, Richard Rimbach Associates, Inc., 845-A Ridge Ave., Pittsburgh 12, Pa.)

27–30. American Medical Assoc., clinical, Seattle, Wash. (G. F. Lull, AMA, 535 N. Dearborn St., Chicago 10, Ill.)

27–30. National Chemical Exposition, 9th, Cleveland, Ohio. (American Chemical Soc., 1155 16 St., NW, Washington 6, D.C.)

28–30. American College of Cardiology, 5th interim, Pittsburgh, Pa. (P. Reichert, ACC, Empire State Bldg., New York, N.Y.)

28–30. International Conf. on Ozone, 1st, Chicago, Ill. (C. E. Thorp, Armour Research Foundation, 35 W. 33 St., Chicago 16.)

29–30. Veterinary Symposium on "Meti-Steroids," New York, N.Y. (J. C. Siegrist, Schering Corp., Bloomfield, N.J.)

30. American Rheumatism Assoc., Bethesda, Md. (E. F. Hartung, 580 Park Ave., New York, N.Y.)

30–1. Oklahoma Acad. of Science, Stillwater. (D. E. Howell, Entomology Dept., Oklahoma A. & M. College, Stillwater, Okla.)

30–1. Tennessee Acad. of Science, Murfreesboro. (D. Caplenor, Dept. of Biology, Peabody College, Nashville 4, Tenn.)

December

2. American Acad. of Dental Medicine, 11th mid-annual, New York, N.Y. (A. Reiner, 114-01 201 St., St. Albans 12, N.Y.)

2–7. Radiological Soc. of North America, Inc., annual, Chicago, Ill. (D. S. Childs, 713 E. Genesee St., Syracuse 2, N. Y.)

3–8. International Cong. on Rockets and Guided Missiles for Continental and Telecommunications Connections, Paris, France. (Assoc. for the Encouragement of Aeronautical Research, rue de Courtly 1, Paris 7e.)

5. Recent Advances in the Chemistry of Natural Products, 8th annual Ciba Foundation Lecture, London, England. (G. E. W. Wolstenholme, 41 Portland Place, London, W.1.)

5–7. Instrumentation Conf., 2nd, Inst. of Radio Engineers, Atlanta, Ga. (M. D. Prince, Engineering Experiment Station, Georgia Inst. of Technology, Atlanta.)

6. Amino Acid Imbalance in Nutrition, Assoc. of Vitamin Chemists, Chicago, Ill. (M. Freed, Dawe's Laboratories, Inc., 4800 S. Richmond St., Chicago 32.)

6–7. American Astronautical Soc., 3rd annual, New York, N.Y. (N. V. Petersen, AAS, 516 Fifth Ave., New York 36.)

6–8. American Phytopathological Soc., annual, Cincinnati, Ohio. (G. S. Pound, Dept. of Plant Pathology, Univ. of Wisconsin, Madison.)

6–9. American Psychoanalytic Assoc., New York, N.Y. (J. N. McVeigh, APA, 36 W. 44 St., New York 36.)

7–8. Association for Research in Nervous and Mental Disease, annual, New York, N.Y. (R. J. Masselink, 710 W. 168 St., New York 32.)

8–11. American Acad. of Optometry, annual, Houston, Tex. (C. C. Koch, 1506 Foshay Tower, Minneapolis 2, Minn.)

(See issue of 19 October for comprehensive list)

EQUIPMENT NEWS

All inquiries concerning items listed here should be addressed to Science, *Room 604, 11 W. 42 St., New York 36, N.Y. Include the name(s) of the manufacturer(s) and the department number(s).*

■ DIGITAL RATEMETER can be used with scintillation counters, Geiger tubes, and proportional counters. A high-voltage supply that is variable from 300 to 3000 v provides current to operate the auxiliary detectors. Input sensitivity is adjustable from 0.2 to 5.0 v. Range is from 0 to 100,000 counts. Time of read-out can be varied from approximately 1.5 sec to 5.0 sec as desired. At the end of each read-out period, the instrument automatically resets itself and displays a new rate of count. (Technical Associates, Dept. S96)

■ ELECTROMECHANICAL MANIPULATOR is designed to provide fully remote operation. The distance between the operator and the "slave" is determined by the length of the interconnecting electric cable. A television monitor can be used to present a display at the control console. Electric controls for indexing and locking the manipulator are provided. (Borg-Warner Corp., Dept. S97)

■ X-RAY DIFFRACTION BROCHURE discusses basic theory (Bragg's law), definitions, analytic advantages, and applications in metallurgy, chemistry, mineralogy, physiology, pathology, and biology. Included are typical patterns of Laue, rotating crystal, and powder methods of crystal study. (General Electric Co., Dept. S41)

■ HEAT-RESISTANT RUBBER withstands swelling by fuels and oils. Hardness, tensile strength, and elongation are comparable to other silicone rubbers. (Dow Corning Corp., Dept. S42)

■ COLORIMETER permits color-difference determination in temperature-sensitive materials and in dusty atmospheres. A cooling system and an air filter are provided. The apparatus performs the functions of an abridged spectrophotometer and a tristimulus colorphotometer in analyzing color formulations, determining metameric conditions, and measuring color differences in hue, value, and chroma. (Instrument Development Laboratories, Inc., Dept. S43)

■ WATER DEMINERALIZER is a table-model, ion-exchange device for direct-faucet connection. A direct-reading meter, calibrated in ohms per cubit centimeter and in parts per million indicates the quality of water being delivered at flow rates of approximately 1 gal min. (Ion-Exchange Products, Dept. S44)

■ VIBRATING REED ELECTROMETER developed for measurement of small d-c currents and voltages at high impedance has a stability of ±1 mv, sensitivity of 0.03 μμa, four ranges, three inputs, and sufficient output to operate with a 1-ma or 100-mv recorder. The instrument is made by Ekco Electronics, Ltd., in England, and operates on 110 or 220-v, 40 to 60 cy/sec electric power. (American Tradair Corp., Dept. S95)

■ PUG MILL MIXER for laboratory use has a variable-speed drive of 20 to 30 rev/min. The instrument is driven by a 0.75-hp motor. (Lindcraft Corp., Dept. S45)

■ STAINLESS-STEEL EQUIPMENT for handling radioisotopes used in biology is described in a new bulletin. Among the units described are a back-mounted incubator, a biological refrigerator, a microbiological filter canister, refrigerated centrifuge, autoclave, and hood. All items are of modular design. (S. Blickman, Inc., Dept. S94)

■ MICROTOME KNIFE SHARPENER uses a revolving glass wheel as the sharpening surface and a soap solution as coolant and vehicle for the abrasive. The knife is manually applied, and the rotational speed of the wheel is set at a fixed optimum for sharpening and for prevention of burning or chipping. There is a micrometer for adjusting the bevel angle of the knife. (Research Specialties Co., Dept. S80)

■ DIRECT-WRITING OSCILLOGRAPH provides instantaneous, permanent recordings of frequencies as high as 250 cy/sec at 1-in. double amplitude. The Datagraph, which has high input impedance, employs a vibrating wire in a magnetic field. The wire burns a contact wherever it touches the electrosensitive paper as it travels over an anvil, providing rectilinear writing. Speed-change pushbuttons select six chart-speeds, and separate control knobs set the trace density for each of the two channels. Both the oscillograph and the companion amplifier operate on standard electric power. (Consolidated Electrodynamics Corp., Dept. S82)

■ SHIELDING BRICK made of transparent plastic permits observation of processes that involve use of high-level sources of radioactivity. Bricks are hollow blocks; they have a sealable hole through which zinc bromide is introduced to provide shielding. (P. M. Lennard Co., Dept. S93)

■ STOCHASTIC GENERATOR is capable of continuous production of random numbers at 10 per second and may be used as a computer accessory. (Loyola Laboratories, Dept. S47)

■ COUNTER-CURRENT APPARATUS uses three-phase solvent-system combinations and provides for automatic or manual shaking. (Laboratory Glass and Instrument Corp., Dept. S48)

■ MULTIENVIRONMENT TEST CHAMBER produces temperatures ranging from $-100°$ to $+400°F$ and maintains them during operation to within ± 2 Fahrenheit degrees accuracy. The stainless-steel chamber has a capacity of 12 ft^3. (Mantec, Inc., Dept. S46)

■ PIPETTE allows centrifugation of a blood sample for hematocrit determinations while the sample is still in the pipette. The pipette is calibrated in sedimentation rates and hematocrit scales. A U-shaped bore prevents the blood from being expelled during centrifugation. (Delmar Scientific Co., Dept. S87)

■ DELAY LINE model 403, designed for use as a component or as test equipment in computer and radar systems, is continuously variable over its delay range from zero to 0.70 μsec. Attenuation is less than 1.0 db; resolution is better than 0.001 μsec; maximum rise time is 0.060 μsec; and impedance is 500 ohm. (ESC Corp., Dept. S78)

■ TYGON FLEXIBLE PLASTIC TUBING is described in a 28-page booklet that covers each of the formulations of Tygon tubing. Applications and limitations of each formulation are presented, as well as physical properties and chemical resistances. (U.S. Stoneware Co., Dept. S83)

■ AIR SAMPLER has an automatic flow control that compensates for changes in the resistance of the filter. (Mine Safety Appliance Co., Dept. S84)

■ GLASS BLOWING ON THE GLASS LATHE is the title of a manual on the basic techniques of using a glass lathe. (Bethlehem Apparatus Co., Inc., Dept. S92)

■ RESISTORS that can operate at temperatures up to 200°C are now available with increased resistance ranges. Maximum resistance has been increased in the ½-watt size to 100,000 ohm, in the 1-watt size to 400,000 ohm, and in the 2-watt size to 1 Mohm. (Corning Glass Works, Dept. S75)

■ LINEAR ACCELERATOR, which is to be used in sterilization programs, has been adapted to full-scale production-line application and is now undergoing final tests prior to shipment. The accelerator has electron-beam power outputs of approximately 2 kw at 2.5 Mev and 4 kw at 5 Mev. At reduced power, the machine will operate at voltages up to 7 Mev. Another model has power outputs of 2 kw at 6 Mev and 4 kw at 10 Mev. This unit will operate at voltages up to 14 Mev at reduced power. (High Voltage Engineering Corp., Dept. S50)

■ RARE EARTH OXIDES imported from the laboratories of Johnson, Matthey and Co., Ltd., London, England, are available in various grades and chemical forms ranging from spectrographically certified purity as high as 99.998 percent down to lower grades. In addition to oxides, an assortment of rare earth salts are available, as well as several metals. (Jarrell-Ash Co., Dept. S81)

■ SILICON RECTIFIERS with welded-case construction and an operating level of 1500 v operate stably at temperatures up to 150°C and have forward current ratings up to 125 ma. The single-element, grown junction rectifiers are available in axial and stud half-wave models. (Texas Instruments, Inc., Dept. S79)

■ NEEDLE VALVES made of Teflon plastic can be used with all types of laboratory glassware when micro measurements are required. A catalog describes various operational uses in chromatography and other fields. (Emil Greiner Co., Dept. S85)

■ ULTRAVIOLET RADIATION SOURCE designed for use in chromatographic procedures operates at a wavelength of 3660 A. A 5-in., heat-resistant, red-purple filter removes visible wavelengths. (Black Light Corp., Dept. S88)

■ CENTRIFUGE permits separation of 160-ml samples at 20 speeds up to 25,000 rev/min and with a force up to 50,000 g. The unit can be operated without refrigeration. A variety of rotors with capacity up to 1 liter is available. (Beckman Instruments, Dept. S91)

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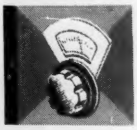

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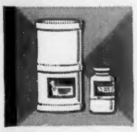

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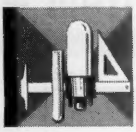

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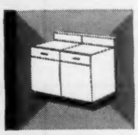

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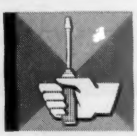

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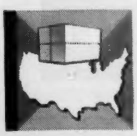

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Emerson, Parr, Precision

CENTRIFUGES
Fisher, International, Precision, Sharples

CHEMICALS
Fisher, B.B.L. Media, Difco Media, Eastman Organics (DPI), National Aniline Stains & Dyes, Travenol Sera

COLORIMETERS
American Optical (Spencer), Bausch & Lomb (B&L), Beckman, Fisher

CRUSHERS, GRINDERS, PULVERIZERS, MILLS
Braun, Fisher, U. S. Stoneware, Wiley

DISTILLATION EQUIPMENT
American Sterilizer, Barnstead, Precision, Stokes

ELECTROPHORESIS APPARATUS
Spinco, Welch

FILTER PAPER
Fisher, Munktells, Reeve Angel, Schleicher & Schuli, Whatman

FURNACES AND OVENS
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FURNITURE
Fisher Unitized (from stock)

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Beckman, Fisher

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Coors, Corning (Pyrex and Vycor), Fisher, Kimble (Exax and Normax)

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American Optical (Spencer), Bausch & Lomb (B&L), Fisher, Precision-Jarrett

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Beckman, Bausch & Lomb (B&L), Fisher-Todd

STERILIZERS & INCUBATORS
American Sterilizer, Fisher, Precision

STIRRERS
Eastern, Fisher, Mixco (Lightnin'), Precision, Waring

TITRATION EQUIPMENT
Beckman, Fisher, Precision

VISCOMETERS
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B-20

■ THERMISTOR THERMOMETER has six separate channels, each provided with five different temperature ranges. The instrument covers the range from 30°F to 110°F in overlapping increments of 20°. Accuracy is ±0.25°F. The portable unit has a mercury battery, and thermistor probes can be used either locally or remotely. (Yellow Springs Instrument Co., Dept. S86)

■ HYDROMETERS for measuring specific gravity or making other density measurements are available in sets with various calibrations. (Princo Thermometer Co., Dept. S90)

■ CUP SINK made of polyethylene is designed to fit in standard laboratory counter tops. It is of standard oval shape and measures 3 by 6 in. A ½-in., pipe-threaded tail piece is provided. (American Agile Corp., Dept. S89)

■ RADIOACTIVITY MONITOR with fixed or moving filter automatically measures and records airborne radioactivity and warns by light and bell when preset limits are exceeded. The mobile unit will operate unattended for 7 to 10 days, and it can follow either short-term, high-level radioactivity or more slowly changing, low-level radioactivity. A flexible collecting and counting arrangement is provided for immediate continuous counting, delayed continuous counting, immediate step-wise counting, or delayed step-wise counting. Features include a positive-displacement pump, count-rate meter, variable-speed chart recorder, and a lead counting chamber 2 in. thick. (Nuclear Measurements Corp., Dept. S52)

■ CERAMIC PERMANENT MAGNETS have the following properties: high resistivity, low specific gravity, high potential energy, and low incremental permeability. Indox I magnets are nonconductors and are hard, brittle, and lighter in weight than magnets made of metallic alloys. (Indiana Steel Products Co., Dept. S49)

■ GALVANOMETER SHUNT is intended to provide greater range for sensitive galvanometers. The redesigned Fisher Ayrton shunt contains carbon-metallic film resistances with individual tolerances of ±1 percent. It has nine switch settings from 1× to 500×. (Fisher Scientific Co., Dept. S51)

■ METALLIC COPPER IN LACQUER SOLUTION is the basis of a new colloidal dispersion that is designed for plating nonconductors. The dispersion can be applied by spray or brush. No baking is required. The film will air-dry and can be handled within a few minutes. (Acheson Colloids Co., Dept. S59)

■ ELECTRONICS-DATA HANDBOOK gives in 64 pages a selected collection of often-needed formulas and data used in radio and industrial electronics. Formulas include those needed for basic circuit analysis, transmission-line calculations, determination of vacuum-tube characteristics, resonance calculations, meter calculations, and so on. (Allied Radio Corp., Dept. S38)

■ PORTABLE SCALER, for use with Geiger-Müller tubes and scintillation counters, weighs 24 lb. A high-voltage supply that is stable within 3 v and a built-in timer to collect counting-rate data are provided. Permitting lower-energy gamma rays to be screened out, the direct-reading scaler permits the operator to discriminate against backscatter radiation in gamma-ray measurements. (Berkeley Division of Beckman Instruments, Dept. S39)

■ VIAL FILLER dispenses up to 8 oz of liquid per stroke and fills vials singly or in multiples of two. Free-flowing or semiviscous fluids, including aqueous solutions, oils, syrups, suspensions, and saturated solutions, may be dispensed at rates variable from 3 to 60 fills per minute. Volume of fill is adjustable from 0.002 oz per stroke on a calibrated micrometer dial. (National Instrument Co., Dept. S40)

■ PORTABLE MOISTURE DETERMINER for use in field stations, laboratories, or quality-control points, weighs 22 lb and can analyze liquid, solid, and gaseous samples. Accuracy of determinations varies from ± 10 percent in the range of 0 to 100 ppm down to ± 0.2 percent in higher ranges. (Central Scientific Co., Dept. S35)

■ VAPOR-PHASE CHROMATOGRAPH can use microsamples and operate with adsorption, gas-liquid partition, and reaction columns to handle a variety of compounds, including liquids with boiling points up to 325°C. The chromatograph will separate isomers of close boiling points and components in mixtures with wide boiling-point ranges. The instrument consists of a control unit and an analyzer, the former containing a power input and distribution system, a system for controlling carrier-gas flow, and detector circuit controls. A chromatographic column, a thermostatically controlled heating system, a detector, and a system for introducing the sample constitute the analyzer. The temperature of the analyzer is adjustable in a continuous range of from 60° to 250°C and is regulated to within 0.5°C. An internal sample valve, which is heated to the temperature of the analyzer, controls the size of gas samples to within ± 0.5 percent. (Consolidated Electrodynamics Corp., Dept. S37)

INDEX OF ADVERTISED PRODUCTS

Classified in the following pages are the products advertised in *Science* in the issues from 28 Oct. 1955 through 19 Oct. 1956. This list is intended to aid laboratory workers in finding the manufacturers of all types of laboratory equipment and supplies. At the end of the classified list is a list of companies that advertised in "The Market Place" section during the period 28 Oct. 1955 through 19 Oct. 1956. An index of advertisers in this issue appears on page 862.

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Sargent, E. H., & Co.
1956: 28 Sept., 558

TUBING

Thomas, Arthur H., Co.
1956: 13 Apr., 648
U.S. Stoneware
1956: 17 Aug., 334; 7 Sept., 453; 28 Sept., 596; 12 Oct., 694

VACUUM GAUGE

National Research Corp., NRC Equipment Corp.,
1956: 7 Sept., 423

VACUUM TUBES

General Electric Co.
1955: 4 Nov., 895

VAPOR EQUIVALENT APPARATUS

Central Scientific Co.
1955: 2 Dec., 1043

VISCOMETERS

Fish-Schurman Corp.
1956: 27 Apr., 755
Fisher Scientific
1956: 5 Oct., 608

WARBURG APPARATUS

GME (Gilson-Medical Electronics)
1955: 18 Nov., 990; 2 Dec., 1056
Will Corp.
1956: 16 Mar., 475

WATER BATHS

Fisher Scientific
1956: 5 Oct., 608

WATER DEMINERALIZERS

Standard Scientific Supply Co.
1956: 8 June, 1050

X-RAY UNITS

Jarrell-Ash Co.
1956: 24 Feb., 306; 27 Apr., 702; 28 Sept., 563

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Beckman Instruments, Inc., Beckman Div.
220 Wright Ave., Richmond 3, Calif.

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Boyce Thompson Institute for Plant Research
Yonkers 3, N.Y.

Budd Mt. Rodent Farm
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Grand Rapids, Mich.

Canner, J. S., Inc.
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117 Liberty St., New York 6, N.Y.

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Chromatography Co.
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Dawson, Kenneth A., Co.
106 Concord Ave., Belmont 78, Mass.

Electro-Medical Laboratory, Inc.
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Ferner, R. Y., Co., Inc.
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Hormone Assay Laboratories, Inc.
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Isotopes Specialties Co., Inc.
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Califon, N.J.

Shankman Laboratories
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Sky & Telescope
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148 Islip Ave., Islip, N.Y.

Stokely-Peterson, Inc.
P.O. Box 1254, Madison 1, Wis.

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Germantown, N.Y.

Target Earth
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Technical Instrument Co.
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Technicon Chemical Co., Inc.
Chauncey, N.Y.

Thermalab, Inc.
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Truesdail Laboratories, Inc.
4101 N. Figueroa St., Los Angeles 65, Calif.

Vantage Press, Inc.
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Wisconsin Alumni Research Foundation
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INDEX OF ADVERTISERS

26 October 1956

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POSITIONS OPEN

(a) **Associate Medical Director**; physician well trained in pediatrics, internal medicine, or surgery; advantageous if expert in marrow area; pharmaceutical company; Pacific Coast; $15,000. (b) **Chief Bacteriologist** to organize department; 500-bed teaching hospital; metropolis, important medical center, East; $6000–$7000. (c) **Clinical Physiologist**, M.D., preferred; Ph.D. eligible; duties consist of research and teaching at graduate and postgraduate levels; university medical center, West. (d) **Research Assistants**; 800-bed teaching hospital; particularly desirable opportunities for persons wishing to change from clinical chemistry to medical research; Midwest. (c) **Mycologist**, Ph.D. or M.S.; course work in taxonomy of molds desired; pharmaceutical company; Midwest. S10-27 Medical Bureau (Burneice Larson, Director), 900 North Michigan Ave., Chicago. X

Research Assistant in research laboratory investigating biochemical aspects of central nervous system function. Opportunity for qualified individuals to simultaneously pursue graduate studies. Salary to $4000. Location: New England. Box 233, SCIENCE. 10/19; 26

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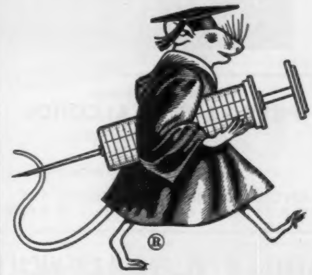

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